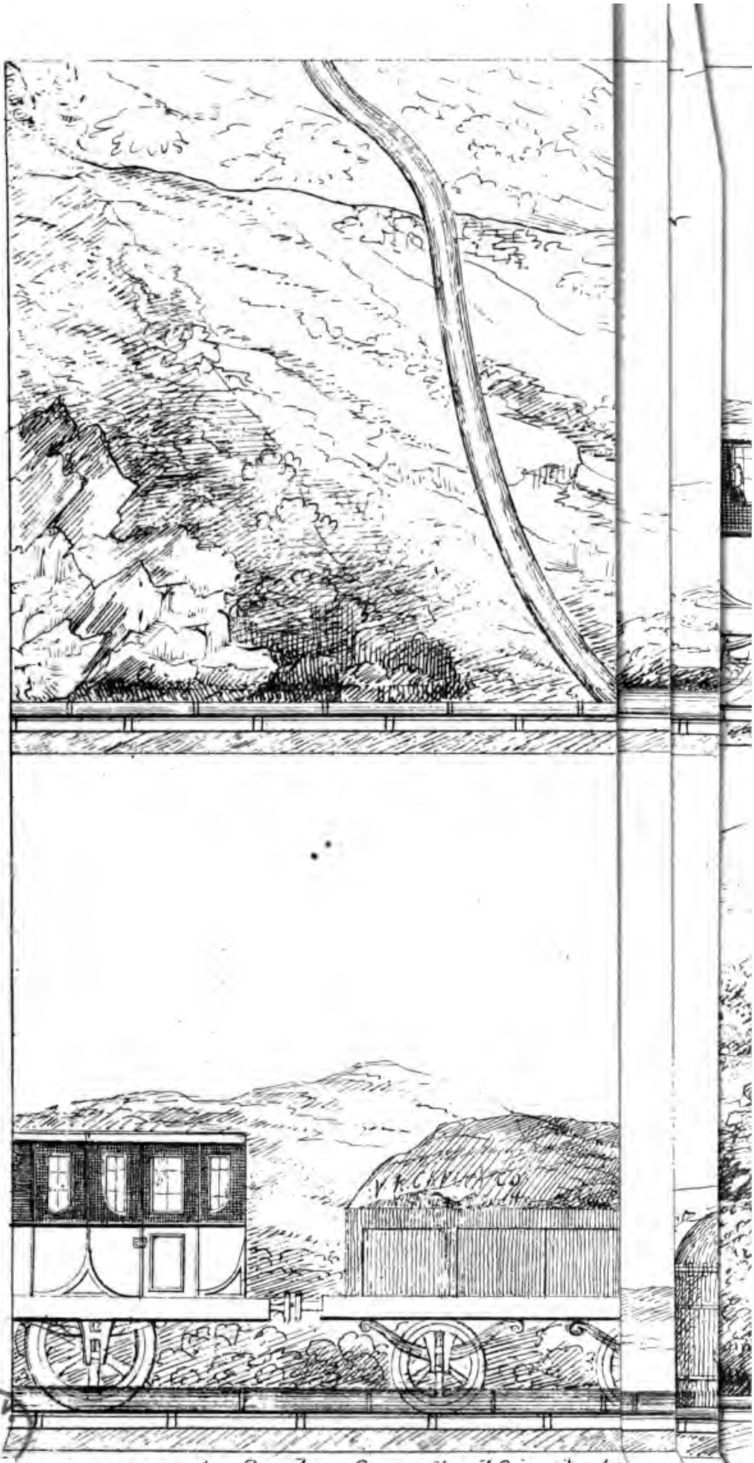
Bind



Drawn to Scale of onehalf inch to ... ex

To J. F. Bateman Esqre
with Richard Roy's best Respects
25th July. 1845.

THE

HYDRAULIC RAILWAY;

BEING A CAREFULLY DIGESTED,

BUT

PLAIN STATEMENT

OF

THE ADVANTAGES TO BE DERIVED, AND IMPEDIMENTS REMOVED,

IN ESTABLISHING

HYDRAULIC PROPULSION,

ON RAILWAYS.

BY J. G. SHUTTLEWORTH,

(THE PATENTEE.)

London:
J. WEALE, HIGH HOLBORN,
MANCHESTER: J. & J. THOMSON, MARKET STREET; SIMMS AND
DINHAM, EXCHANGE STREET; AND ALL BOOKSELLERS.
1842.

MANCHESTER:
SIMPSON AND GILLETT, PRINTERS, 78, MARKET STREET.
1842.

ADVERTISEMENT.

It is hoped that the attempt, which will be manifest in this pamphlet, to render the subject-matter of it, with its several ramifications, interesting to the general reader, will be viewed in the right light by the engineer, and man of science. It is desirable that every one, who has the opportunity, and however humble his pretensions may be, should study to make the subject of any writing, which may furnish occupation for the mind, and exercise for the mental faculties, as widely acceptable as possible; and this, with much pleasure, it may be observed, has become a leading feature in many of the more recent scientific publications. It may be also mentioned, that the invention, which is advocated in the following sheets, is of a nature which seems to suggest the propriety of its being introduced, if possible, to the public, through the medium of such a style of writing, as may render it generally simple and easy in its perusal to such members of the community at large, as may take up the pamphlet; but still, so as not to detract from the interest, which philosophic and learned minds, and practical mechanicians, may feel in the question at issue.

The writer of this pamphlet is anxious also to avail himself of this, as being the earliest opportunity, to apologize for the length of it. But, when it is remembered, that a treatise on railways, or on the locomotive, or stationary engine, is not looked upon as having, within 500 or 600 pages, reached an unreasonable extent, it is hoped, the length of the present pamphlet will not be objected to, as it comprises the clear explanation—if the writer is competent of this—of a re-adjustment of no small portion of a most extensive system.

PREFACE.

There are two ways of writing a book; one is by putting a colouring, as it is termed, on the subject of it, and veiling or distracting attention from its least promising features; the other is by meeting the question fairly and at once, in its most unfavourable aspect; with the assurance that if this is successfully encountered, the question will gain strength from the investigation, in the exact ratio in which seeming obstacles in the way of its advantages, have been removed. I have preferred the latter mode. I do not wish to give others the trouble of pulling this pamphlet to pieces. This may often be done in the spirit of perfect honesty and to demonstrate the truth; and, when so undertaken, the dissection of a publication—for it is no longer a mere pulling to pieces—is not the less severe because the operation is performed with urbanity; indeed, when strict and not unfriendly truth is the dissecting instrument, and the subject-matter is *diseased,* the cut is frequently deepest.

I have therefore met the question, which I have set at issue, in its several branches, in its least favourable development, and have reviewed the subject under the light, which science and its acknowledged principles throw upon it; testing that review by accepted data. I may have made mistakes, notwithstanding the long and deep study and attention, which I have bestowed upon this question; particularly as the subject is new, and the arrangement therefore of its several ramifications, and the proportioning throughout of its machinery, have been no trifling undertaking; but I do trust that nothing like an intentional error will be considered, by any candid reader, as apparent in the following pages:

At the same time let me not deceive any one. For about a period of twenty years, a soap-maker by position, and from peculiar circumstances, strictly a secret student of some branches of science, by choice, my pretensions must be as humble as my opportunities of acquiring the best, most available, and useful information were for a long period limited; and it will not, I flatter myself, be expected by men of reflecting minds, that the terms of art will flow as freely in these sheets, or that the range of science—especially in those branches, to which it was not in my

power to devote any particular attention, will be as freely open to me, or its language as familiar to my pen, as if art and science had been the whole, or at least the main, occupation of my life. From any awkwardness of manner or arrangement, I appeal to the subject-matter, and from any imperfection in style of writing or diction, I appeal to the question at issue. If that question is worthy of attention, and is found to hold out good promise of beneficial results, either to the community at large, to the scientific world, or to Railway shareholders, the phraseology in which it is dressed, and the manner in which it is treated, will, I feel assured, by the general body of my readers, be esteemed far less worthy of their attention than the grounds on which it is presented to their notice, and the probable soundness of the position it assumes.

I have often found awakened attention in the subject of scientific works strangely interrupted, and the ideas or conclusions to which they were drawing the mind of the reader, awkwardly checked, by lengthened references to plates and drawings, with all their minutest detail, in the midst of the most interesting portions of such works. In the present instance, to remedy this, as far as the case may admit of, I have separated much of this sort of description from the body of this pamphlet, and have preferred attaching a sort of tabular reference or index to the drawing, at the end of the book. For the same reason, I have there been rather more explanatory on the general nature, and some of the various parts of the invention, than is usual in a "Description of the Drawing;" so much so, I hope, as to have rendered it capable of furnishing, to many of my readers, a preliminary general idea of the principle here called into operation, and of its probable effects. Still, I have been very desirous throughout the pamphlet, to avoid an extreme minuteness of description wherever all was manifest, both as regards th machinery and its action—instances of which, are sometimes met with that would be almost amusing, if time were no object whatever, and i attention could be given, long after the understanding was satisfied The references however are more numerous than I anticipated on subject so simple; but my first surprise at this was removed, when considered what number of references would be requisite to describe th whole machinery of a locomotive, and what greater number must b added, if, not a locomotive only, but also a large portion of the who working system of railway were, according to its present arrangemen and for the first time, to be brought before the public.

Still, I may have occasionally treated some portions of the gen subject of this treatise, in a manner that may appear lengthy to se of my readers. My object has been to render the matter, where it w all material, clear. At any expense of labour to myself individu

and even at the risk of seeming tedious, it has been my wish, whenever the subject to be considered was anywise of moment, and there could be reasonably any doubt as to my meaning, to go into further illustration, and to leave as little as possible to be guessed at. That method —which saves trouble—of leaving a reader to *unriddle* a book, and of keeping the conjectural powers on the stretch—and of necessity occasionally throwing them at fault—is, on the long run, in writings of this description, the most tedious and unsatisfactory manner possible, of treating a subject.

I think I need only at present add, that, as the practicability of Hydraulic propulsion will be generally admitted to be a question of the first importance, I have thought it right to submit most, if not all of the sentiments I offer upon it, in the following investigation of the subject, to the consideration and friendly advice of several of the most able and scientific men, to whom I have the honor of being known. I hope it will be allowed, I have thus avoided the censurable or unreasonable course of inviting a portion of public attention to a proposition and invention of this magnitude, on pretensions of equivocal merit, or at least, on which the public have expressed no opinion.

I gladly take this opportunity of offering my best acknowledgments to those gentlemen who have kindly favoured me with suggestions and advice on the several occasions, on which I have availed myself of their friendly offices in the following pages.

2, Tiverton Street, Ardwick Toll Bar, Manchester,
June 25, 1842.

Errata.

Page.

IX. Principal Contents, chap. 2, in 3rd line, for "Eddûs" read "Eddies."

X. ,, ,, chap. 6, in 13th line, for "and power" read "pow

XI. ,, ,, chap. 8, in 1st line, for "propulsions" read "prop

10. Line 21, for "in the development" read "in development,"

13. ,, 3, for "deau" read "d'eau."

14. ,, 19, for "barker's" read "Barker's."

21. ,, 31, for "atmosphere" read "atmospheres."

26. ,, 23, for "force" read "face."

32. ,, 34, for "liquid" read "the liquid."

33. ,, 1, for "propulsive momentum" read "propulsive force and mom

35. ,, 31, for "as the square of 27 is smaller than that of 86½" read "as of the velocity is increased between 27 and 67 5-6ths, wh equal to 6¼."*

47. ,, 28, for "skeleton-length" read "skeleton-section."

51. ,, 6, for "let" read "Let."

51. ,, 7, for "being there" read "be therein."

55. ,, 9, for "allow" read "which will allow."

56. ,, 2, for "abundant" read "incumbent."

59. ,, 33, for "due water" read "due to water."

60. ,, 1, for "37 seconds" read "41 seconds."

60. ,, 15, for "2¼" read "2 3-8ths"

62. ,, 5, for "drawing" read "driving."

64. ,, 32, for "air-pressure" read "water-pressure."

65. ,, 38, for "wire" read "wire rope."

66. ,, 8, for "intouse" read "into use."

66. ,, 10, for "where" read "anywhere."

79. ,, 19, for "38 × 50" read "38 × 150."

84. ,, 29, for "must claim" read "must moreover claim."

87. ,, 27, for "considered" read "answered."

87. ,, 31, for "on its success, are borne in mind" read "are borne in r success."

89, ,, 37, for "four" read "five."

92. ,, 29, for "confirm to the" read "confirm the."

92. ,, 36, for "formulæ" read "formula."

93. ,, 12, for "unfavourabe" read "unfavourable."

93. ,, 21, for "tied" read "fixed."

101. ,, 29, for "axle of the driving truck" read "axle of back pair of w driving truck."

103. ,, 33, for "connectng" read "connecting rod."

** This alteration would make a trifling difference, if followed out, in the figures which have yet tc subject of the initial velocity. The author can only say, in extenuation of this, and other minor mista pear, that this little work was written, and carried, (hurried,) through the press, when he was suffe impaired health; and while the whole responsibility of working out these, and most of the other calcu upon himself alone.*

PRINCIPAL CONTENTS.

CHAPTER I.

CHAPTER II.

CHAPTER III.

CHAPTER IV.

CHAPTER V.

CHAPTER VI.

CHAPTER VII.

THE

HYDRAULIC RAILWAY.

CHAP. I.

THE first and great objects of science—particularly of mechanical science—are, through physical acquisitions, to advance the general happiness of mankind. To add to the conveniences and economize the means of the human race, is generally tantamount to promoting material comfort, domestic happiness, and social enjoyment; it is often, the same thing as to remove the pressure of contracted circumstances, to give buoyancy to the mind and to restore vigour to the human frame. Objects such as these, constitute the best claims of science on public support and general esteem.

The grand achievement of late years, in mechanical science, has been the establishment of railways. These, with their wonderful machinery and general economy, engross no small share of the attention of the whole of the public, from its lowest members up to "Home Secretaries," both in Europe and America. Another quarter of the globe is likely soon to feel their influence; and railways must shortly become most interesting subjects of enquiry, as respects the prospects they may offer for the advantageous investment of capital—embracing necessarily the modes and opportunities for their construction and practical arrangement—in India, if not also in other parts of Asia.

It would be trite then to say that railways are concerns of national importance. No one disputes it; their results would negative such an assertion. Their share market claims its place in the public journals, by the side of the stock market:

places which were remote, are, through their agency, and for all practical purposes, no longer so; and time which was lost, is now saved. A man may drop asleep in his travelling "easy chair," in a railway coach in the evening at Darlington or Lancaster, and wake, with the early dawn, in London. Correspondence, which was tardy and lagging, now flies from one end of the Empire to the other, at a speed, totally eclipsing that which government couriers, but a few years back, boasted when mounted on the fleetest horses. The community, in many of the comforts and necessaries of life, have equally experienced the beneficial effects of the railway system, as the state of the meat, the poultry, the vegetable, and other markets in the larger towns sufficiently testify; and the great manufacturing marts are benefited to an extent which, though closely observed by comparatively few, is too great for any but a political economist duly to calculate. The agriculturist also derives great advantage from the proximity of a railway, in the swift conveyance it offers him, for the produce of his farm to market.

Railways therefore in their effects as at present developed, may, without the slightest exaggeration, be said to be wonderful; and in the development of their future effects, they are already working a change in the whole framework of society, peaceable and without strife, which in a comparatively short space of time, is likely to exhibit to the world, consequences of a magnitude greater than those which have arisen from revolutionary convulsions, the march of victorious armies and the longest wars; and in most respects of a character, very opposite to that of the results, which such epochs in history have afforded. Napoleon himself pointed to a road (the Simplon) as the most lasting and trustworthy monument of his glory: little did he imagine, that even his great work must sink into comparative insignificance before the labours of a few years' continuance, of English engineers—without considering the great railway works on the continent and in America—when supported in their stupendous undertakings by the countenan of the British public, and aided by the powerful lever of Brit capital.

When these effects are borne in mind, and when it is recollec that, where we travelled at the rate of ten miles an hou

which, fifteen years since, was considered a maximum exertion—we now *glide* over the country at a speed of twenty miles, or more; and when it is remembered that places, which, as regards the public at large, were considered so remote as to be seldom or never visited, unless the emergency of the occasion rendered such an effort indispensable, are now "run down" to, in a few hours, as being merely a morning's trip; and when also the tradesman recollects that he can now have his goods down in the country in a few hours, which on the old system, required several days in transit; it will not appear extraordinary that the wonder of the public at this great change, should for a time have so far absorbed its clear powers of reflection, as to render it nearly indifferent to the question as to whether its first expectations of the benefits to accrue from this extraordinary feature of our times, had been altogether realized; and whether improvements, every way advantageous, could not yet be introduced into the system of locomotion. But it appears the period is arrived when enquiry is beginning to resume its wonted energy; and questions are now exchanged every day among the community at large and in the public prints, indicative of doubt whether the locomotive system has at once started into existence in a state of absolute perfection, and, unlike every other invention which the world ever witnessed, incapable, at least in its leading features, of all improvement. It was anticipated, not that time only would be saved, but also that the expense of transmission either of goods or individuals, would be considerably reduced by steam-locomotion, in which iron supplies the place of horses, and coal, the place of hay and corn; but the enormous annual cost of "maintenance of the way," including the whole locomotive department, has, for the present, set that question at rest. It was expected that this mode of travelling would be exempt from frightful casualties; and "railway accidents" now occupy a conspicuous place in the columns of every weekly journal. It was greatly hoped—almost promised—that this system would extend its arms right and left, till it reached into every town and populous locality; but the public were at length informed, better experience had demonstrated, that these "Branches," if established at all, must be undertaken by each separate town, and that the good burgesses, to accomplish such desirable objects,

must be prepared almost literally to cover the foundation of their proposed railways with gold. And punctuality, as regards time of arrival, seemed with the apparently powerful moving engines, a circumstance of easy and certain attainment; while it is now proved that wet, frost, fogs, wind, and the numerous minor accidents, to which the machinery of locomotives is so peculiarly subject, render all certainty as regards the time of arrival, both with respect to passengers and mails, frequently much more questionable by railway-locomotion than on the former system of travelling, by coaches on the turnpikes.

Such appearing to be the actual position of the railway system at the present time, it is imagined that this pamphlet is offered to the public and railway proprietors not inopportunely; and it is therefore hoped, that its statements, calculations, and propositions will be received with the frankness and candour in which they are offered, and will be considered with the care and attention due to proposals, which, if founded on correct data, embrace in their principles, much public benefit, and, as respects railway shareholders in particular, great individual advantage and profit.

The author begs to state, that he has submitted his invention to the first scientific and engineering characters, with whom he has the pleasure of being acquainted, and, though solicited to point out any objection to the working of his system, if any such were apparent, nothing of such a nature has presented itself to the minds of any of these gentlemen; indeed, the answer has frequently been, that the system appeared so reasonable in drawing and description, that it was now advanced into that position, which called for its merits being brought to the test and decision of a full practical trial. Though something, partly of this nature has been already alluded to in the preface, it seems not improper to repeat this here; for hydraulics is a science which has been less popular and less studied than several others; hence, its capabilities may not at first, and until they have been a little enlarged upon, be so fully appreciated by some of my readers, as they deserve. But the powerful agencies which this leading branch of hydronymics commands, offer it, particularly in its wider ranges and more active energies, as a subject well worthy of attention. Its greatest capabilities have been much over-

looked, or but passingly alluded to, especially in what is termed "popular information," and their place has been supplied by amusing accounts of *jets d'eau*, adjutates, fountains, and all the trifling water-work gambles which this liquid was made to play for the pleasure of Louis the 14th at Versailles; and in mere illustration of which, some of the experiments still quoted in works on hydrostatics, appear to have been originally undertaken; while many facts, demonstrations and conclusions which much research and study can furnish, afford striking indications of this science being not remotely destined to step in with its great resources, as a first mover of machinery much more frequently than it is now. It is a science less perfected, and with its forces and proportions less developed and demonstrated —or when demonstrated they are so through the medium of formulæ, which, though based on experiments, are generally arbitrary—than many others which cannot claim its gigantic powers and capabilities to work well for mankind;* but it is to be hoped that most of the mist which may still hang around some of its nobler proportions, will be shortly cleared away; for attention has been drawn to this subject from a quarter well deserving of respect and notice.†

In the meantime, fully sufficient has been done in this science to elucidate, for all practical purposes, the subject I am now to treat, and upon which I shall be particular to make myself clear in the following sheets; after the perusal of which, it will remain for my readers to decide whether this application of hydrostatic propulsion does, or does not hold out strong and reasonable promise of its capabilities to move forward our railway system another step in its extraordinary career,—probably scarcely less efficient, as regards simplicity and power, and generally as little anticipated by the public at large, as was its former advance by locomotive engines, prior to the opening of the Manchester and Liverpool Railway. I will now, therefore—avoiding technical

* See Note A.

† Rev. William Whewell, who, in his "History of the Inductive Sciences," and in the chapter on "The Discovery of the Mechanical Principles of Fluids," remarks, "Even up to the present time mathematicians have not been able to reduce problems concerning the motion of fluids to mathematical principles and calculation, without introducing some steps of this arbitrary kind."

language as much as I can, and taking perspicuity and clearness for my guide, in order to render myself as widely understood as possible—proceed to explain my system of hydraulic propulsion, in as far as it has reference to railways. The scientific part of the description particularly, which I am now to give, shall, for the reasons above alluded to, be written in the most familiar and simple terms I can apply to it.

As the term hydraulic will be known to imply, my system of propulsion is founded on the laws which regulate liquids in motion, and particularly on those important principles which govern water in its passage up pipes, and the force which it then exhibits, if under any material pressure. That pressure, it will be apparent to many of my readers, may arise either from the liquid being conveyed to a horizontal main, from an elevated reservoir, by vertical or oblique piping, or it may originate in a supply of water, placed under the condensed atmospheric pressure of an air vessel;—the first acting medium in this latter case, I would here remark, may, as convenience and opportunities offer, be either a barker's mill, a water wheel, a steam engine, or an hydraulic engine of that peculiar and effective construction which, as far as cylinder, piston, valves, and reciprocating action are concerned, assumes the features of a steam engine. But, having said thus much for the satisfaction of my scientific readers, it will be better to postpone all explanation of the mode in which the agency and power of such media may be rendered active and economically available for this system of propulsion, till we get further into the subject.

The effective pressure exhibited by water in pipes, is, in fact, familiar almost to every one. Who has not, in the days of his childhood, if residing in a town, amused himself by pressing his finger firmly upon the mouth of the diminutive pipe, which supplied his home, from the neighbouring "main" of son water works' company, with water, and who has not remark the pressure requisite to restrain even a stream so very smal But, probably, the juvenile observations of many have be satisfied with these facts, and have not prompted those inquir which might have procured for such young observers the inf mation, that these little pipes, whose gush of water so m surprised them, are frequently "throttled" by a brass ring

introduced to contract the bore, where these small conducts join the main; thus, in some degree, controlling the supply and restraining the impetuous rush of the liquid.

To recall another familiar instance of the power of hydraulic pressure to the minds of my general readers, I will just allude to the hydraulic press, the enormous power of which, when once it has drawn observation, is not likely to be soon forgotten. In the words of Dr. Arnott, in his Physics, "Scarcely any resistance can withstand the power of such a press; with it, the hand of an infant can break a strong iron bar; and it is used to condense substances, as cotton or hay, for sea voyages, to raise great weights, to uproot trees, to tear things asunder, &c."

Many instances of the prodigious effects of hydraulic pressure will immediately recur to the minds of my scientific readers, whether they turn to the works of art, and recollect the blowing up of culverts, reservoir, canal and river banks, and the dreadful eruptions, while constructing, in the Thames Tunnel, &c., or whether they reflect on the operations of this pressure, on a far more widely extended scale, in the phenomena of nature; where this power removes hills, uplifts districts, or, when withdrawn, allows them to sink; loosens and throws down the heads of deep cuttings on railways, projects the noblest natural fountains, inundates mines; and, in its more active state, with the aid of its momentum, lifts masses of rock from the beds of torrents, and hurls them into other localities. It has even, as geologists affirm, heaved these huge fragments of an antideluvian world from the bosoms of valleys, or torn them from the mountains, and, carrying them over countries, kingdoms, and seas, has eventually deposited them on spots, hundreds of miles remote from rocks of all kindred character.

And, to address myself again to general and popular observation, and to what is every day to be witnessed, as a familiar instance of the effect of hydraulic action, I need only mention the common lifting or pumping steam engine with its hydraulic machinery. The term steam engine is synonymous with power; and the effects of this term and its realization in practice, are to be witnessed all over the United Kingdom, and in every part of the high seas. This power has raised the population of Manchester from some thirty or forty thousands to upwards of three

hundred thousands; and would Acre, the *impregnable* Acre, have been so easily captured, and our other exploits recently in the Levant, or at the present time taking place on the coast of China, prove, with so much facility, the wonderful superiority of Great Britain, without the aid of this power? And, yet, when the steam engine is brought to act upon water, I am not, I think, guilty of exaggeration, when I say, it goes tremblingly to work; witness its slow heaves and *pauses* as its machinery reciprocates its action; observe its air vessels to moderate the shock of the water when its progress is interrupted, and, if the pump be large, attend to the clash of its valves. A power like that of water is not to be reciprocated without due caution; throw a little too much momentum into a substance so ponderous, yet, when once in motion, so responsive to the lift of the engine; so incompressible yet subtile, and, but for the air-vessel, it would seriously strain, if not fracture, the ponderous, but well-proportioned machinery, even of the steam engine itself!

Still, under able engineers, all these apparent elements of discord are so well equalized into harmony, that the steam engine forcing or lifting pump, is everywhere to be found contributing greatly, in one of its most ordinary positions, to the comfort of the population of London, and many other of our towns; where it becomes the medium for supplying their inhabitants with wholesome water. I mention this, more clearly, to bring before the minds of my general readers, the power of my propulsive medium; not to convey to any one the idea that I shall apply that medium with a reciprocating action up my propulsive piping; far otherwise; for the power of the rush of the water, or, in other words, its momentum, will be entirely unchecked by any reciprocation, and all in the direction in which I require it to propel the piston, and, through that, the train.

It is true, I shall occasionally apply the steam engine forcing pump as a *first medium* for conveying propulsive power to the water. That is, where natural heads of water of sufficient elevation, or smaller falls to work hydraulic machinery, are not, by the aid of piping, within convenient reach. The question of the distance from which water might be conveyed, to furnish supplies to reservoirs, under adequate pressure, to feed the propulsive pipes, is less material, than the question of amount of

expense, and the consequent length of connecting pipe, which, in an economical point of view, would be advisable—for water might be brought, from elevated ground at a considerable distance, without material retardation in the pipes, or consequent loss in propulsive power, if pipes of sufficient bore were laid to convey it, so that it should travel along them, at a speed comparatively slow. Steam engine lifting, or rather force pumps, therefore will be, as I have just intimated, occasionally indispensable; and on such occasions I rely on the great results which such engines afford in Cornwall, for their agency proving far more economical on railways, than a cursory glance at the question might induce us to imagine. The opinion I now offer, I trust I shall be able fully to establish to general satisfaction, when I come, in the following pages, to the details on this matter. Cornish steam engines consume 2½ lbs. of coal per horse power per hour, while the Manchester factory-engines, under the same conditions, consume 10 to 12 lbs. or even more; and other stationary engines, of the ordinary construction, are esteemed very successful mechanism, whenever they can bring down their average consumption of coal to 8 lbs. per horse power per hour.

The duty obtained from the Cornish engines is *now* undoubtedly very great; but what would it become, should the "pliable solid," as water has been aptly termed, which they have to lift, be eventually as completely subdued by engineering skill and perseverance, into perfect and immediate tractability, as the prodigious force and rush of steam is at the present moment in the steam engine itself.

This is not to be considered very hypothetical. What is now more common than the high-pressure engine? How could the locomotive be worked on any other principle? How could the Cornish engines perform their present amount of duty without it? And yet, Mr. Watt, himself, in early life, after testing this principle by experiment, pronounced it to be impracticable; though he lived to see the time, when this was proved to be a mistaken conclusion, and when he availed himself of what further experience had manifested. After so much has been accomplished in steam, particularly in the case of the Cornish engines, it would be rather hazardous to affirm that the water with which

those engines at present contend, with marked success, shall not yet become more immediately ductile and responsive under the reciprocating action of their powerful great beams. The power of the natural flow of water in a continued stream can be estimated, and the result so obtained is very great; but the ebb—or pause—and flow of the water on the Cornish principle, must detract much from the efficacy of those great and still successful engines; and it is to be hoped, the period is not far distant, when the science of hydraulics will be so far advanced as to enable them to bring up the water in one continued stream, and without sacrificing, as at present, the momentum which, with the first energy of their high pressure steam, they create in this strong incompressible liquid, and suffer again to die, after every lifting stroke they make. Though the stream so established, would be in a vertical, instead of horizontal direction, yet the comparison here instituted, as respects the amount of its effects, and the difference between a free natural flow of water and an intermitting stream, will, in the two cases, hold good, when the circumstances are borne in mind, to a sufficient extent to justify its being adduced in illustration of the idea now advanced.

A material characteristic of liquids, is their disposition to acquire a true horizontal level. The first use they make of the facility of motion by which they are distinguished, is to exert it in regaining this level, whenever it has, from any cause, been disturbed. It matters not whether a torrent has precipitated itself down the face of a mountain, or a river poured itself into one side of a lake, or whether one end of a tube full of water, has been bent upwards, or whatever else may have occasioned the disturbance of the water-level; that level, if the liquid be left to itself, will be regained, and the more speedily regained, in exact proportion to the extent or height of the disturbing cause. Distance cannot neutralize this law of hydrostatics. Whether the surface or horizontal column, whose level has, at one side been disturbed, be ten yards, ten miles, or any other measure in length, the liquid immediately begins to exert the power of motion, inherent in it, under such circumstances, to regain its true horizontal level; and it never will be in an absolute state of rest, until that is accomplished.

I have already alluded to the fact, that the water-works of

some of our large towns supply water to the inhabitants, through their mains and branch pipes, in all their wide and extensive ramifications, by means of powerful force-pumps. The principle here in action, may properly be considered as a branch of the same law of hydrostatics; as the reason that fluids seek to regain a true horizontal level, is, that by breaking it, the equalization of pressure throughout their whole volume, has been disturbed, and this cannot be, without the law of gravity being equally broken. The power of gravity, then, aided by their extreme facility of motion, immediately comes into action, to recover its own natural effect, by replacing under its influence, the liquids in a state of rest. Hence, whether the level—or say the law of gravity—has been disturbed by the pressure of a vertical, or oblique column of water, raised above the main column, or by that of an air vessel; or whether it be, by the plunger or ram of a steam engine force-pump, that pressure becomes tantamount to an infraction of the law of gravity, and the liquid, if not impeded, rushes forward, under influence of that power, to restore to force, its interrupted law.

Some large towns however, which are favourably situated in hilly districts for the purpose, obtain their supply of water from the immediate action of this law of hydrostatics, which impels all liquids to seek the lowest level presented to them. These places present fine examples of this law in wide operation. They have their supply-dams placed among the hills, sometimes at a distance of several miles, at a sufficient elevation above the highest part of the town; and the water being conducted down to the town, by large pipes or mains, is there distributed, as occasion may require, in every direction, whether high or low; provided only, that the point of supply be at a level somewhat lower than that of the supply-dams or reservoirs.

The water or spirit level, which is usually attached to our barometers, in order to act as a guide to hang them in a true perpendicular line, is a familiar instance of the action of the same law, on a very small scale; and a similar spirit level is, on account of its extreme truth and accuracy, an indispensable appendage to some of the surveying instruments, used by our civil engineers, as well as to certain philosophical apparatus.

I have been thus particular, in the latter part of this intro-

ductory chapter, in explaining, sufficiently for this stage of the question, the nature of hydraulic pressure; and I have shown something of its effects, exhibited in torrents, in piping, or in open sheets of water, as the principle on which my plan of hydraulic propulsion is founded, is dependent on this law, particularly when taken in its more extended sense; namely, that when the equalization of pressure throughout a liquid volume is overpowered by any other pressure, or an outlet has been permitted to it, the liquid, under certain conditions, will rush, as I may be allowed to express it, into space, and exert a power to recover in some lower situation, its natural horizontal level, with a vehemence proportional to the amount of pressure which, whether inherent in itself or borrowed from any foreign body, has been the cause of its disturbance.

If however, the elementary or practical branches of hydrostatics which I have thought it desirable to sketch in this chapter, have been described in a manner that might be considered as bordering upon prolixity, it should be remembered, this has been done under the impression, that hydraulics is a science, which, particularly in its wider ranges, has not yet received that share of public attention, to which its importance entitles it. I may also add, that the necessity of rendering the whole subject, to which I now invite attention, as generally intelligible as possible, has been strongly urged upon me, from a judicious and experienced quarter.*

* See note B.

CHAPTER. II.

I have said my propulsive power is to be derived from the pressure of water in vertical piping, or from some equivalent to such vertical pressure, otherwise obtained; and I have already endeavoured to convey some general idea of the power so to be derived. The two principal questions then, which will test the practicability of this mode of propulsion, now clearly demand attention. They are;

1st,—The proportion or amount of power, to be obtained as above intimated, under given conditions.

2nd,—The speed or velocity, with which such hydraulic power will travel, through the medium of connecting horizontal piping, when acting as a propulsive agent, for railway purposes.

These two questions will require very careful consideration, in order to put a numerous and respectable portion of the public, who may not probably, heretofore, have given attention to such subjects, sufficiently in possession of the scientific principles which these questions involve, to enable such individuals, in common with others, to form a general estimate of the practical results, which these investigations promise.

The first question is one of very easy solution, if understood as being proposed under its most simple conditions. Thus, the pressure and propulsive power, at the foot of any vertical column of water, of one even bore throughout, will, upon proper means being taken to apply it, be found to be identical with the weight of the water contained in that vertical column; and which liquid is, at the foot of it, pressing downwards, with its whole weight, there to escape. For instance, I propose to make my propulsion piping one foot in diameter; and I should wish, in all ordinary circumstances, to place such piping under a pressure (vertical or otherwise,) at first, equivalent to six free atmosphere. Now, as a vertical column of water, 33 feet high, is considered a counter-

poise to the atmospheric pressure, when of average density*, it will require a column of water, 198 feet high, to counterbalance a pressure of six atmospheres; and as every circular, or rather cylindrical, foot of water weighs 49 lbs., the whole pressure, under such conditions, will amount to $\left(\frac{198 \times 49}{112}\right)$ 86 cwt. 2 qr. 14 lb. This quotient, however, conveys to the mind but a very imperfect idea of the power derived from such a source, which would be found to be available as a propulsive agent for railway purposes. It will be influenced by the action of several laws in science; in the first place, while it must be at once admitted that, in the ordinary phraseology of the profession, a free pressure of 86 cwt. 2 qr. 14 lb. represents, or is tantamount to sixty-five horse-power, (as every ton of pressure, or of free, disengaged lifting power, is substantially esteemed to be the work of fifteen horses); yet, all this pre-supposes that this pressure shall propel, or this vertical lifting, shall be accomplished, at the rate of 220 feet a minute, or two miles and a half an hour, which is considered the average steam engine speed. If the work is done twice as fast, twice the effort has been made; and accordingly the power which has accomplished this, is properly and accurately considered, twice as great as in the former supposition. In the same way; if the power have accomplished its work in a third, or a fourth part of the time, it is estimated as being three or four times as great in amount, and so on. When I proceed, as I shall do immediately, to the consideration of the second question proposed at the commencement of this chapter, and on which the subject already touches, I shall have to show the natural rate, speed, or velocity of fall, of such a head of water, and in such piping as I have just described. It will be found that the acceleration of speed and consequent multiplication of power, under the given circumstances, will be very greatly in favour of this mode of propulsion.

The above effect being borne in mind, will prove of great importance in hydraulic propulsion, in the way of correcting any error in calculating the amount of the power of this first active

* "Now as the air's pressure near the earth, by several undeniable experiments, may be proved at least to be equal to the absolute weight of thirty-three feet of water, it will at all times counterbalance, and, therefore, raise and sustain that quantity."—*Clare's Motion of Fluids.* Page 46.

agent—if this should be occasionally estimated by its weight or pressure *only;* as is done, not unfrequently, in the case of the steam engine, on account of its nearly uniform rate of motion—by immediately drawing the attention back to the question of the *speed,* and requiring that this important item shall be duly admitted into the account, before any calculation can be presented, as accurate and trustworthy. But while the natural speed or velocity of the fall of water down vertical piping, will prove so greatly in favour of this system; yet, to arrive at a correct estimate of the effects, it must not be overlooked, that a considerable deduction must be made from this advantage, in respect of velocity, for the friction or retardation of the water, in the vertical and horizontal pipes; in the former, this retarding influence will be of small amount; in the latter, it will be more considerable,—and this at once introduces the second question to our deliberate and calm consideration. It embraces, within its investigation, much of the practical or working effect of hydraulic propulsion.

One of the first laws in mechanics informs us that a body, whether fluid or solid, falling *freely* through space, accomplishes, in equal times, distances, which are, relatively to each other, *as the odd numbers:* that is, a body is found to fall 16 feet, (or to approach nearer to mathematical accuracy, we should say 16 ft. 1 in.) in the first second; it will, in the next second, fall through three times that distance; in the third second, through five times; and in the fourth, through seven times the same distance, and so on. We also know that the distance fallen through, in any interval of time, *is as the squares of the times;* and that, in two seconds, it will have fallen through 16 ft. $\times$ 4; in three seconds, 16 $\times$ 9; in four seconds, 16 $\times$ 16, &c. Also, though a body falls through 16 feet in the first second; yet, at the *end* of that second, it is falling at the rate of 32 feet; and this being kept in mind, we know that the rate or speed of descent, is *as the times,* and that, at the end of every subsequent equal interval, it will be falling at the rate of 32 feet, multiplied by the times, or number of seconds, through which its descent has been continued; at the end of the second second, its rate of descent, at that moment, will be 32 $\times$ 2, at the end of the third second, 32 $\times$ 3, and so on.

It would be very desirable, if it could be demonstrated that principles, so easy of application, govern the fall of water in closed vertical pipes. Authorities might be brought forward to support this doctrine; and could it be established, it would make inherent in the mode of propulsion I advocate, a still greater amount of power than I at present feel justified in claiming for it; but it too frequently happens, that these authorities, when they claim so much, in some other portion of their own works, accidentally show that such estimates are in error. Thus Desaguliers, translating Marriotte, at page 170, alluding to the accelerating speed of descent in falling bodies, says: "The water running through the (vertical) pipe would increase *according to the odd numbers,* if there was only the pipe." But the reason he assigns for this assumption is quite unsatisfactory; and the context, in the work itself, a little lower down, negatives the idea. Clare also might be quoted to the same effect. This may be observed in a portion, in italics, of the passage I have extracted from him, at the end of this pamphlet, as being, in his rather quaint language, beautifully illustrative of some peculiarities in the vertical fall of water, as well as of other bodies.* One of the authors of Tredgold's Tracts, (Venturé) also hazards the same assertion, stating that "The fluid stratum, continuing to descend through L C (a cylindrical tube) *tends to accelerate its motion according to the laws of gravitation*"—(page 139, second edition.) This, I am afraid, is one of those instances in which he entitles himself to the observation which Tredgold makes in his preface, on the inferiority of his judgment, and which remark, of the very able editor, I have already transcribed in Note A.

In that note also, there is abundant confirmation in the well-merited eulogy it bestows on Dr. Young's work, of the great security of the basis on which I place myself when I accept the formula, which Tredgold derives from Dr. Young's Summary of Eytelwein's Hydraulics—in rejection of more favourable principles, which the preceding quotations would seem to authorize —as the foundation of my caculations in the following pages. This rule or formula does not show that water in vertical piping, falls exactly according to the laws of gravitation, or with the whole velocity due to them; and for this sufficient reason, that

* See Note C.

bodies, descending according to those laws, must fall *freely* from a state of rest; whereas, water, descending through vertical piping, is exposed to two retarding influences; neither of them certainly, in the present instance, great in amount, but together they produce a sensible effect. The first is friction, or more properly termed by Tredgold, retardation; for it seems difficult to imagine friction, in the ordinary sense of the term, in the passage of a smooth liquid, like water, through an almost equally smooth pipe. This retardation will require our most careful attention, when we come to consider its effects in horizontal pipes; and it cannot be altogether overlooked, in this, our present inquiry, as to the cause of water departing from the ordinary laws of gravitation, in its fall through vertical piping.

All fluids, whether elastic or non-elastic, have a disposition to stick, or adhere to the sides of the tubes; and if the fluid in immediate contact with the side of the pipe is retarded, the fluid which is next adjoining it, in the moving column, must to a certain extent feel the effects of the contiguous retardation. This is one cause of friction: and there is another, which arises from fluids having a tendency to form eddies, in their passage through pipes, or other channels. The smallest obstruction in the pipes intercepts the free course of a certain portion of the fluid, while the fluid itself, in passing over this portion, turns it round and round, and either drags it away from the cause of interception, for other eddies to be formed there; or, if nôt sufficiently powerful to do this, maintains in it a velocity of revolution, which in a manner condenses and forms the obstructed and obstructing fluid, into the shape and character of a revolving cylinder; and it will then impede the free passage of the descending column exactly in proportion as its bulk—or, to speak more accurately—as its section is to that of the fluid which is passing over it. Now, though on account of their springing or rebounding tendency, elastic fluids will have the greater disposition to form eddies, yet, it must be admitted, that the eddies of non-elastic fluids will, though smaller, be more solid; they are, however, well defined and incapable, at first, of a whirl, and afterwards of a gradually condensing or compressing, and wrapping up within their vortex, of more volume, as may occur in the case of elastic fluids; and, in vertical piping,

they are easily carried down with the liquid; till increasing their speed as they roll, they gradually again commingle with, and are lost in, the body of the descending mass. In vertical piping, therefore, the retardation from this cause is small; and it is also found to be trifling in that just previously named. The other partial obstruction also—which obtains only in vertical pipes—is not of much greater moment; and though its effect, as well as that of the retardation, which I have just explained, is included in the formula, which I am about to introduce to the reader, I will here endeavour shortly to describe its character.

Water falling freely through a vertical pipe will, particularly if the pipe be of any length, have a *tendency* to create a vacuum in some part of it, owing to the water towards the top of the pipe, being, according to the laws of gravity, disposed to fall at a slower rate, than that towards the bottom of it. This is well alluded to in Note C, to which I referred the reader two or three pages back. Now this tendency to a vacuum is beautifully counteracted by the pressure of the air, which at the top of the column, acting on the head of the water, forces it down the pipe with a velocity greater than what is there due to it from gravity, to fill up what would otherwise be vacuity. At the bottom of the column, the same pressure of the air becomes of opposite effect; and there meeting the force of the discharging water, partially obstructs its free egress, and allows the water towards the top of the pipe—with the aid of its own air-pressure—thus to maintain with the rest of the descending column, one well connected stream. Thus the pressure of the air divides its effect in preventing a vacuum in the pipe, equally between the top and bottom of the descending column of water; thus too, from its partially obstructive pressure on the bottom of the column, it detracts something from the velocity due, by the laws of gravitation to the descent of a vertical column of water through piping.

Ample deduction from the velocity of water in piping, for the retardation due to the above causes, as well as that due to the liquid in its passage up horizontal pipes, is made in the formula or rule in Tredgold's Tracts on Hydraulics, which I have promised to bring under the notice of the reader.*

* See Note D.

For reasons, which will be sufficiently obvious, this formula or rule is much influenced in the amount of effect which it indicates, by the diameter of the pipe; and after a good deal of reflection, I have arrived at the conclusion, that the most convenient diameter for my driving or propulsion pipe, on a line of any considerable traffic, will be that of one foot. This will, in the first place, keep the pipe within very moderate dimensions; in the next, it will be of adequate capacity to conduct and render applicable, an horizontal column of water fully sufficient for working, with powerful effect, any railway now established; and in the last place, in a pipe of a foot diameter, I shall have to make less provision against the retarding influence of friction, than in one of smaller bore, for instance, one of six inches; because the friction, according to the commonly accepted rule, is as the diameter, whereas the supply is as the square.

It appears reasonable, also, to regulate the load of the working pressure on the propulsion column of water, as near as possible to those pressures, which are to be found in practical application among the great lifting or pumping engines. Not having at hand the exact length of the lifts of water in the great mines in Cornwall—which, however, must be considerable, as some of the mines are 500 yards, or more, in depth—I find by the printed description of an engine, constructed on the Cornish principle, by the eminent engineer, William Fairbairn, Esq., to drain a mine 720 feet deep, at Verviers, in Belgium, that two of the lifts, or rather lengths of pipe, are 180 feet each, the water, in both cases, being forced up by a plunger or ram. The pressures also to which some of the water works' companies subject their pipes, are occasionally very high. Even in this town (Manchester) in the midst of a comparatively flat district, the water works company's pipes are worked under a pressure of 140 feet ($4\frac{1}{4}$ atmospheres), and when of from 12 to 18 inches bore, and $\frac{7}{8}$ of an inch in thickness, are warranted to stand a pressure of 300 feet, to which they are proved; and I am assured, from sufficient authority, they would bear a great deal more. It will therefore be quite within reasonable limits to place the propulsion pipes for this system, under six free atmospheres at the commencement of every section of piping, and under five at the end of it. I shall occasionally require half an atmosphere extra, though not in the

propulsion pipes; but on this subject, and also as regards the reason for working, first at six, and then at five atmospheres, as well as respects the dimensions of each "section" of the piping, just referred to, more will be said further on. For the present therefore, assuming that at the power-stations, the available force will be limited to that of six atmospheres—which is all the pressure I should wish to avail myself of, when I use these stations to furnish propulsive action to the driving pipes immediately contiguous—I find, by the formula I have given in the last note, that my initial velocity, at the foot of the vertical column, or its equivalent, will, under six atmospheres, represent a speed of full 67 $\frac{5}{8}$ miles an hour. The above initial velocity of course must be checked, or what could stand against it? and nothing can be more easy than to adjust the communication valve, placed between the vertical and horizontal pipe, so to open (partially) *at first*, as to give that amount of supply of water, which will furnish the decreased velocity, or nearly that, due to the further end of the pipe, when the retardation has been taken into calculation. The communication valve to effect the above purpose, is first acted upon by the pulley, as shown in the drawing, which, on being lifted by the inclined plane attached to the travelling truck, raises the valve about one-third: after this, the remainder of the opening is effected gradually by a little machinery, I also show in the drawing; it is done in such manner, as to preserve, in the propulsion column of water, through its whole course up the pipe, one equable velocity; and which clearly must be the same as the final velocity; thus, as the velocity first allowed to the water, in its progress up the pipe, tends to abate, this again tends to increase it, so as to preserve in it one unvarying speed throughout the whole of the pipe, now under consideration. This action of the communication valve illustrates one of the most beautiful laws in hydrostatics, and which is usually exemplified by the hydraulic press or by the hydrostatic bellows. These instruments show, that by contracting the upright pipe (in the case of the bellows, for instance), and thus reducing the supply of water, you reduce the speed or the quickness with which the instrument acts—for the speed is under complete control—but by doing so, *you nowise do, or can reduce the available pressure, and lifting power of the water:* that, under all circumstances,

remains, in the like position, and while the height of the supply is not altered, precisely the same; for it is governed by the area of the base, multiplied into the height of the vertical column, and not by the area of the orifice of the supply. This law in hydrostatics, will be found to afford great advantages to the system of propulsion, now under investigation, in which the moving piston, particularly when near the vertical column, may be considered, for all practical purposes, the base of that column.

To return to the dimensions of the pipes, which I promised to give two or three pages back, I beg to state that I propose to work this system by sections of propulsion piping of 70 yards each, of a diameter of one foot internally, and divided from each other, in ordinary circumstances, by what I term, sections of skeleton piping, of 150 yards each; so that the sections of propulsion or driving pipes alternate with sections of skeleton piping. The reason of this arrangement I will make clear, after I have now given the rate, and in the following chapter explained the nature of the final velocity, which must previously be well understood. The consideration of the amount of propulsive power due to this system, under different conditions, can then be resumed with every opportunity of arriving at a clear and satisfactory conclusion; and this, it will be remembered, constituted the first question, proposed at the commencement of the present chapter.

We now, therefore, require the final velocity of a horizontal column of water, namely that due at the further extremity of each section of propulsion pipe; or in other words, at the mouth of a pipe one foot in diameter, and distant 70 yards horizontal, from the power head. It should always be borne in mind, that, though the initial velocity is obtained under a pressure of six atmospheres, the final velocity must claim the impulsive effect of five only. Under all the conditions now mentioned, this final velocity will be found to be equal to a speed of $27\frac{1}{6}$ miles per hour.

Before I proceed, I will recapitulate the preceding results. I will also insert a few more data, as this may save the delay and trouble in working out the figures, if they should be wanted for purposes of comparison.

Water as a propulsive agent, under a pressure of *six* atmospheres, and in tubing of one foot diameter, furnishes;

(1) At the foot of the vertical column, a free power, driving weight, or impulse, for the purposes of propulsion, of	86 cwt. 2 qr. 14 lb.
(2) An initial velocity, in the same position, (if there uncontrolled) of	$67\frac{5}{6}$* miles per hour.
(3) A velocity in the horizontal pipe, at a distance of 50 yards from the vertical column, of	34 ,, ,,
(4) A velocity at a distance of 70 yards, and which I have termed "final," of	$29\frac{3}{4}$,, ,,
(5) And if each length of horizontal propulsion pipe were to be considered as measuring 100 yards, instead of 70, the water would, at that distance from the vertical column, command a velocity of	$25\frac{3}{5}$,, ,,

All the conditions being the same as the preceding, except taking the propulsive pressure as *five* atmospheres, then

No. 1	would be	....	72 cwt. 0 qr. 21 lb.
,, 2	,, ,,	....	$61\frac{9}{10}$ miles per hour.
,, 3	,, ,,	....	$30\frac{6}{7}$,, ,,
,, 4	,, ,,	....	$27\frac{1}{6}$,, ,,
,, 5	,, ,,	....	$23\frac{2}{5}$,, ,,

If under *four* atmospheres:

No. 1	would be	....	57 cwt. 3 qr. 0 lb.
,, 2	,, ,,	....	$55\frac{2}{5}$ miles per hour.
,, 3	,, ,,	....	$27\frac{3}{5}$,, ,,
,, 4	,, ,,	....	$24\frac{1}{4}$,, ,,
,, 5	,, ,,	....	$20\frac{9}{10}$,, ,,

If under *three* atmospheres:

No. 1	would be	....	43 cwt. 1 qr. 7 lb.
,, 2	,, ,,	....	48 miles per hour.
,, 3	,, ,,	....	$23\frac{6}{7}$,, ,,
,, 4	,, ,,	....	21 ,, ,,
,, 5	,, ,,	....	$18\frac{1}{7}$,, ,,

* Should I have any future opportunity, I can, if it should appear to be desirable, reduce these, and other fractions introduced in different parts of this pamphlet, into decimals: but at present it appears to me hardly consistent to speak of any practical effect, on a large scale, in hundredths. Would it seem reasonable in any colloquial discussion undertaken with a view to decide upon and improve the speed on the London and Birmingham Railway, to say, that at that time the average speed on that line was, for instance, $21\frac{79}{100}$ (substantially $21\frac{4}{5}$), miles per hour, but that it would be brought up to $22\frac{48}{100}$ (substantially $22\frac{1}{2}$).

CHAPTER III.

Having already mentioned, that it appears to be a reasonable course, and clear of either extreme, to propose working under propulsive powers of six and five atmospheres (which, in the language of the steam engine, are respectively equal to 90 lbs. and 75 lbs. pressure, or nearly so, on the square inch) I shall found the several calculations and estimates I may, in the course of the following pages have to offer, on these bases; and which, consequently, to be correct, must be in accordance, as far as it goes, with the preceding brief synoptical view of hydraulic power and velocity.

From all that has preceded, it appears, therefore, that this mode of hydraulic propulsion claims a velocity, as due to it at a distance of 70 yards from each power station, of $27\frac{1}{6}$ miles per hour. I shall *claim* no more for it; though there are strong grounds for presuming that the formula from which I derive this velocity, is inadequate duly to measure the effect and power of liquids, when rushing up pipes of large bore; particularly if then under the impulse of a powerful momentum. In one passage, I have quoted from Tredgold's Tracts in Note D, illustrative of the principles on which his formula is founded, it is stated that the friction will be "inversely as the content of the section or as the *square* of the diameter;" but a gentleman resident in this town (Manchester) whose scientific attainments in hydrostatics are beyond dispute, and whose opportunities of testing his acquirements in the science practically, are as decidedly favourable as his opinion on such subjects is universally respected, has mentioned to me that the results of his own experiments and those of an able scientific friend, have caused him to arrive at the conclusion, that, in pipes of large bore, the friction will not be found to be reduced inversely as the square of the diameter, but more nearly as the *cube* of the diameter.* The misfortune is, that the great bulk of the experiments which form the basis

* See Note E.

of all the data, in works on hydronymics, have been undertaken with apparatus very inadequate to indicate the whole results of hydrostatic phenomena, when that science is called into a state of its widest and most powerful usefulness. The expense was too great to allow of apparatus being furnished, expressly to illustrate the power of this science in its greater operations. Hence, as opportunities were not afforded for determining this by direct experiment, analogy has been called in to furnish what was supposed to be a probable result; just as from analogy an argument might have been founded, before the opening of the Liverpool and Manchester Railway, on the probable power and velocity of the locomotives, from a lecturer's diminutive model of one of those engines. Or, when anything more practical than these diminutive apparatus was brought to bear on the question at issue, so little was known of the actual state of the machinery; of the accuracy, or otherwise, with which the piping was laid down; of its being clear of, or partially obstructed by air in it; the flexures in it, so much detracted from its free efficacy; and so inadequately was the great and powerful momentum of the water, by trying the higher velocities, brought into operation; that no data so obtained, were, or could be anywise likely to exhibit the full amount of the result sought for.

Having stated thus much to set myself right with the public at large, and also to render it pretty manifest that I do not claim *too much*, I have now only to repeat that I am prepared to found my statements and deductions, confirmatory of the power of hydraulic propulsion, on Tredgold's formula: it is the best, that, under all the circumstances, I can produce; or rather, I should say, it is the one most generally accepted, and least open to be demurred at, or questioned by any parties, on the score of indicating too favourable a result. I claim, therefore, no more than 27 miles an hour—though the actual speed is more likely to prove 30 or upwards—but this is on assumption, that I take my driving velocity at that due to liquid at a distance of 70 yards from the vertical column, and control the great previous velocity down to the same rate. The velocity due to the water at fifty yards from each power station, might, probably be very safely taken as the driving speed, and each length of propulsion pipe would then, in the same degree, have to be curtailed; but it is far better to

have a little too much propulsive momentum, in an invention of this description, till proved in practice, than to run the risk of being anywise short of free power, and thus, from unevenness in the effect, to expose the trains, however remotely, to shocks or jerks, in their progress along the line.

I have now to refer my readers to the drawing and the reference to the figures, which will be found at the end of the pamphlet. The alternation of the sections of propulsion and skeleton piping there exhibited, particularly in Fig. 8—where, however, no proportions could be observed—will suggest, as a question; how the trains are to be carried over the skeleton lengths? I answer: they will be carried over the skeleton piping, with very trifling loss of speed (the exact proportion of which I shall soon have to consider,) by the very great momentum thrown into them, through the medium of the travelling piston, in their passage over the propulsion sections. What is the amount of this momentum? At the foot of the vertical column there is a weight, or load of water of 86 cwt. 2 qr. 14 lb. pressing to escape at a speed of $67\frac{5}{8}$ miles per hour. It may otherwise be termed a pent-up flood, seeking means of escape under this enormous pressure, and ready to bear before it, whatever is brought against it with a less opposing power. Now, to repeat a former statement, and save my readers the trouble of referring back, the drawing shows the machinery, attached to the communication valve. The inclined plane on the driving truck, through the agency of the pulley, &c., opens that valve at first, say, one third, so as to allow only such a supply of water through the opening, as shall at first furnish a speed of, *not quite*, 27 miles an hour. Then, as the train progresses, the aperture in the pipe under the valve, opens wider and wider, under the gravitating power of the load, so as fully to counteract the increasing retardation in the horizontal pipe, and to preserve in the water a velocity equal to that under which it first started; or rather, it will be a little increased. Now this is all perfectly easy of accomplishment. On inspecting the drawing of that part of the machinery, which is to effect this purpose, it will be found that the whole is as capable of being adjusted to the speed and circumstances under which it has to work, as a clock is by its pendulum, as a stationary steam engine, by its governor and throttle valve,

or as a locomotive, by its regulator. The pulley, which is acted upon by the inclined plane, attached to one side of the truck, and which, through the intermediate leverage and rods, carries a first motion to the communication valve, may be moved and fixed a little lower or higher, so as to give that proportional first motion to the valve, which shall furnish, as may be found requisite, more or less than one-third of opening for the water to pass through in its passage up the pipe; the load (3) acting on the communication valve, may be raised higher or lower on its arm (2) to afford it more or less power for speedily lifting that valve, and completing its opening; and the air cylinder (c), which regulates and governs the action of the above load, by its piston (e), may easily be made to allow a more active and speedy fall to that load, than the cylinder itself appears at first adjusted for, if it should be found that the load does not complete the opening of the valve *a little* before a train—at the speed for which all this is to be regulated, 27 miles an hour—quits the propulsion section of piping. The air cylinder would effect this purpose by having a tap affixed in it, near the bottom, and which might be set open to what was found to be the true regulating point. This tap is not represented in the drawing; but it is all clear enough, and saves unnecessary detail there. When these adjustments are once arranged in practice—and that, in each case, they would be, in the course of a few hours—they last for ever; for all being once *set* to, and for a given speed, nothing can vary it; heavy or light trains must go before it at one even progression; as the propulsive power is, beyond all comparison, great, and most effective, but regular in its action, when brought to act upon either.

The initial propelling force, or that due at the foot of the vertical column, has been stated to be equal to a pressure of 86 cwt. 2 qr. 14 lb.; and it has been shown that its *natural rate of speed*, in that position is 67$\frac{5}{8}$ miles an hour: it has also been made apparent that this speed must be controlled, so as to reduce it to that of 27 miles an hour, which, as it is the final, must also be the constant speed in each section of propulsion-pipe. The question then arises, what power (say, horse power), for the purposes of propulsion, is represented by a vertical column of water, of the weight of 86 cwt. 2 qr. 14 lb. falling—and as it falls, ap-

plying its gravity, as power—at the rate of 27 miles an hour? But before this can be satisfactorily answered, another question suggests itself, which, as it effects the result, and the reply to the preceding question, must have prior attention. This is the question: Is the above initial power free, or is it subject to any deduction whatever? I must reply that the initial *velocity* is free, ample allowance being made in the formula for the friction of the pipe; but this initial *power*, which now demands our attention, is not quite free; and we must at once proceed to make that deduction from its first amount, which shall set the remainder of it absolutely free, and disposable as a propulsive agent. The rate of the fall, or the discharge of the water, due at the foot of a vertical pipe of one foot diameter, and under six atmospheres, or 198 feet in height, is 99½ cylindrical feet of water per second; but this rate of fall or velocity, of 99½ feet, is that due, by the laws of gravity, to a descent of about 150, when bodies fall freely through space. Thus, provided I employed this propulsive power on my machinery, at the velocity here due to it; then, of the vertical column of 198 feet in height, 150 feet would have to be considered as the free gravitating agent, and 38 feet as that employed in overcoming the friction due to the pipe. This is exactly in accordance with the views on this subject, expressed by the learned editor of the Tracts on Hydraulics, as may be found transcribed in Note D. But instead of taking the above natural velocity, as I may be allowed to term it, of such a column for propulsive effect, I limit the velocity to that of, say, 27 miles an hour. Hence, while in the former case, a deduction (16 cwt. 2 qr. 16 lb.) would require making, which would reduce the gravitating power to 70 cwt. in the present instance, the deduction must be as much reduced as the square of 27 is smaller than that of 86½. This will detract from the first gravitating power, say 86 cwt. 2 qr. 14 lb. by very nearly 1 cwt. 2 qr. 14 lb.: thus leaving 85 cwt. absolutely free.

Now we can return to the former question, and easily determine the horse power, represented by the gravitating power of 85 cwt., falling freely, through space, at the speed of 27⅙ miles per hour. As a horse power is represented by the free lift (or gravitating power, either) of 150 lbs. at the rate of 220 feet per minute; and, consequently, as the free lift of one ton, at the rate of

$2\frac{1}{2}$ miles an hour, is substantially tantamount to fifteen horse power, I have only to multiply $4\frac{1}{4}$ tons (85 cwt.) by 15, and I have $63\frac{3}{4}$ horse power, *if moving only at the rate of* $2\frac{1}{2}$ *miles an hour;* but, as $27\frac{1}{6}$ is very nearly eleven times that rate, the result will be affected, nearly in that proportion; or to bring it out with more accuracy $\left(\frac{63.75 \times 27.17}{2.50}\right)$, I find there will be a free initial propulsive power of 693 horses.

Hence, it appears clear, that, without claiming anything for the *momentum* of this ponderous, solid, rapid torrent—and as it starts, at this moment, into a state of activity, from one of absolute inertia, I shall not here ask for the allowance of any further effect, as due to this system of propulsion, from that source —its initial effect upon the travelling piston will be equal to that of a steam engine of 693 horse power.

What its final effect will be—namely, that at the further end of the propulsion pipe—must be next considered.

The rate of discharge of water, due to a pipe of one foot diameter, at its mouth, at a distance of 70 yards from the vertical column, and under a pressure of 5 atmospheres, is 40 cylindrical feet per second, (by the formula, exactly 39.8 feet per second) and this velocity, is that, due by the laws of gravity, to a free fall of 20 feet. Hence, as a cylindrical foot of water weighs 49 lbs., therefore, $49 \times 20 = 980$ lbs. $= 8$ cwt. 3 qrs. 0 lbs. of free, falling, and propulsive power; which at $27\frac{1}{6}$ miles an hour, is equivalent to 71 horse power. The remainder of the pressure of the vertical column, when the water has travelled 70 yards from its base, is, therefore, by the formula, to be considered as being expended in overcoming the friction due to the pipe; and on the assumption, that *so much* of the initial pressure, due to five atmospheres—which initial pressure is 72 cwt. 0 qrs. 21 lbs., will be so expended, I shall proceed with my calculations; first, only requesting my readers to compare in their own minds, the amount of this deduction, with all that has been said in the preceding pages, respecting the present state of hydrostatic knowledge, as regards the progressive force and power of water in *large* piping, at very high velocities, and under a great momentum, proportionally increased. The experiments from which the probable effects, in opinion of the experimenters, have been deduced, bear nearly the same relation or proportion to the

question at issue, as an enquiry into the hydraulic power of a river, running rapidly and freely in a deep bed, would, if undertaken upon data, obtained from the observed effects of the hydraulic force of a brook, running a tortuous course, over a pebbly bottom; or otherwise, from those of a phlegmatic *dike*, trailing its way, at a few miles an hour, through some wide level.

My readers too, I trust, will bear in mind, the nature of the information and observations in note E, and particularly those in the context, upon which that note is founded.

Proceeding therefore, with my inquiry, into the free available power of this system, I have only now to urge, that the momentum and impetus, which would be as nothing comparatively, in the diminutive column of water, due to any pipe of small bore, seem to have been as much overlooked in the case of large pipes, as they justly, have been in smaller ones; while, in effect, in pipes of considerable capacity, such forces would, if foolishly checked, become literally overwhelming. Who would dare to check a locomotive, when—to use a very significant phrase—it was at its "full swing?" and yet, at that moment, and under such speed, its driving, or tractive power—from which source only, it can maintain, or feed its momentum—is usually estimated as being only that of about 800 lbs. And in like manner, who would stake his judgment on the assumption, that a column of water, which, but five seconds before, started into action, under an enormous gravitating force—say 86 cwt. 2 qrs. 14 lbs. as due to six atmospheres, under which it starts—shall, in that short interval, have so expended its power, as then to present a remaining progressive effort of hardly 9 cwt.? Water, when inclosed in pipes, is less compressible than the metals themselves; and is, under these circumstances, perhaps, best compared to a mass of molten iron. Now, of what character would the momentum and impetus be, of a horizontal column of iron, 70 yards long, and one foot in diameter; and moving as freely as water is every day observed to do, either in closed or unclosed canals, at a rate of 27 miles an hour? Iron, though less incompressible, is far more ponderous than water; that must be admitted. Let the difference then be deducted, and the estimated result calculated; or at any rate, let a just idea of the power here in question, remain impressed on the mind. It should also, never be forgotten

that, though I propose to set the communication valve to a speed of 27 miles an hour, as being that which the formula directs me to consider due to the final velocity; yet, should it prove in practice, that the momentum, and mighty rush of water, up the capacious pipe, have power, materially to accelerate this final velocity, and to impart to it, for instance, a speed of 30 or 35 miles an hour, there is nothing whatever to prevent the first (partial) opening of the communication valve from being adjusted accordingly. It can be regulated, to furnish throughout the whole length of the pipe, any final speed, which shall, as it necessarily must, be lower than the initial speed; namely, that of $67\frac{5}{8}$ miles an hour. As far as relates to the arrangement of the machinery, for reducing this great hydraulic power into utility, and obtaining from it a safe, practical effect, it will be found, by the drawing that I wish to provide a sufficiently capacious air vessel (S) at the end of every section of propulsion piping, to receive, what would be the *shock*, of the horizontal column of water, if suddenly checked, and gradually to destroy, and render perfectly harmless, the immense impetus with which it will be then advancing. When the water rushes into these vessels, it will be thrown upwards by their internal arrangement; but it will be met in them at first, by an ordinary atmospheric pressure only; that pressure however will be rapidly increased, as the space into which the air is condensed, above the water, is rapidly diminished, by the entrance of the impetuous current; until at length, the one increasing, and the other decreasing, the rush of the water will be gradually subdued, and the fluid brought again into a state of quiescence.

CHAPTER IV.

I must now leave this momentum to demonstrate its own amount of power, whenever called into action. My case, I think is strong, and I can do well without it; and it might distract attention from the main question at issue, were I too much to insist upon it here, when it appears, either that it has not occurred to very high authorities to consider what may be expected from it, or else, that their calculations were undertaken merely to determine the effects of water in its slow course, through the tortuous piping, for the supply of towns. But there is a momentum, under another character, though acquired from the first driving power, the mighty agency of which I cannot consent to relinquish, in my estimate of the effects to be produced from this mode of hydraulic propulsion. The momentum I now allude to, is every day witnessed in operation; and is that which is absolutely inherent in a train in motion, especially when at the higher speeds. Such momentum—or, say impetus—when ungoverned, has been the cause of too many lamentable accidents, to require any further observations on the power or force while it exists, which it carries in it. Whenever, therefore, I can show that this propulsive force, or medium of force, can be rendered practically available in hydraulic propulsion, I claim its powerful agency. I shall have to bring this subject more fully under the notice of my readers, when the time comes to demonstrate its effects.

Let us now consider a train as coming under the action of one section of propulsion piping. For present purposes, it will be best to suppose that it has got up its speed;—indeed, the mode of getting up the speed will probably suggest itself to my readers at once. It is clear, the first section of propulsion piping from any station, may be extended to a length of, say 100 or 120 yards, and the communication valve, being set to give a very small speed at first and gradually to increase it, till it affords that due

to the end of such section, so much of the required speed will be got up; and the rest can, with equal facility, be obtained by proportionate adjustment, and similar in character, from the next—and it may be immediately adjoining—section of propulsion pipe.

A train of the gross weight of sixty tons, on the present locomotive arrangement of railways, would be represented by a train of the gross weight of 40 tons* on the hydraulic system; as, on this plan, the locomotive engine and tender, with their loads, will be dispensed with—their substitute, in the present instance, being the driving truck, which must, or at least ought, to carry a load in order to keep it firm and well down to the rails; thus it becomes no useless incumbrance, as far as profitable carrying properties are concerned. It is true, the smaller compartment at the back of it is appropriated to the driver (there being no stoker required) and guard, or conductor; but that compartment, or addition to the truck, will add so little to the weight, that it is not worth taking into account. I may observe, the guard will be at the driver's elbow to communicate his orders, and not placed on a carriage at a distance from him; when the noise of a locomotive train very frequently prevents his orders being heard by the driver, when the urgency of the occasion is greatest. It will be perceived that the adaptation of the truck for conveyance of merchandise, has been considered in the position of the wheels; and that the safety of the conductor and driver have been kept in view, by placing them in the back part of the carriage, *in case* of any collision;—the occurrence of which, though impossible in hydraulic propulsion from the usual causes—may still, at remote intervals, take place on this system, in common with every other, if high-roads are permitted to cross the lines, or cattle to stray upon them. When considering the arrangement of the conductor and driver's department, it will be evident that the truck must carry heavy goods only, to lay in the body of the carriage, such as metals, masonry, and heavy packages; and so as not to intercept the look-out a-head, of the men in charge of the train.

* M. de Pambour, in his elaborate work, shows that the average gross loads on the Liverpool and Manchester Railway, in the year ending June 30th, 1834, were 32 tons each. This includes the weight of the goods, passengers, carriages, and trucks, but not that of the engines and tenders.—*Practical Treatise on Locomotive Engines, second edition*, p. 542.

A train, then, so arranged, and of such gross load (40 tons) may be considered as quitting a section of skeleton pipe, and as just approaching a propulsion section. At that moment its speed will have fallen a trifling degree, say from a mile and a half to two miles an hour; but this point I shall demonstrate a little further on. This, however, for the present being assumed, and the train being considered, as then at about 25 miles and a half an hour, its travelling piston is conducted into the pipe, and the valves acting, as explained in the reference to the drawing, the hydraulic pressure at once comes into action, and carries the piston, with the train attached, before it. This pressure I have shown to be enormous in amount; hence, if it instantly struck the piston with a velocity of 27 miles an hour, when that of the piston itself did not represent more than 25 miles and a half, a jerk would take place, and be felt through the train, very similar to those jerks which are now so common when a locomotive first proceeds to put a train of carriages in motion. In the hydraulic system, however, a jerk of the character I am describing, would clearly not be near so rough as that which, under the circumstances alluded to, is felt in a locomotive train; for, in the latter case, the carriages have no motion in them, while, in the former, the impulse would only tend to vary their speed from 25 miles and a half, to 27 miles an hour. Any liability, however, to a sudden impulse, even of so trifling an amount, is, with the greatest facility, removed, by adjusting the communication valve to open, just at first for 25 miles, and immediately afterwards to run up the speed to 27 miles an hour.

As soon as, or the moment after, a train is acted upon by the vertical column of water, or its equivalent in pressure, I have shown that it is placed under an impulsive force equal to that of a steam engine of 693 horse power; and it will be evident, that, should the speed be increased—the first driving or gravitating load on it, being still the same—the available horse power must be advanced in a like proportion. Indeed, if it were possible to avail ourselves, for propulsive purposes, of the whole initial speed, due at the foot of the vertical column, the horse power would swell up to such a prodigious amount, that, *if the figures did not clearly demonstrate it*, I should never venture to refer to it in print.

"Now, what is the tractive force which a locomotive engine of ordinary power, can exhibit at the higher speeds? I have already intimated, that it is usually estimated as being equal to the gravitating power, or load of 800 lbs. falling freely with a similar velocity. But this, in fact, appears to be in excess. Dr. Lardner, in his lectures on the resistance of railway trains, delivered in Manchester, the beginning of 1840, states (see these lectures reported at length in the *Guardian* newspaper for February, 1840) that the whole resistance upon railways is equal to 22 lbs. or 23 lbs. per ton, when the speed is 30 miles an hour. His opinion, on this subject, is of great weight, as his deductions are the results of very extensive practical experiments, made on the Liverpool and Manchester, and also the Grand Junction Railway, under the auspices of the Liverpool and Manchester directors, expressly to determine the whole amount of retardation, which a train has to encounter, under given circumstances. Dr. Lardner states that this retardation includes the opposing influence of the air; he also points out the fact, that the retardation of the trains, which, at 30 miles an hour, he estimates at 22 lbs. to 23 lbs. per ton, decreases *very rapidly*, as the speed falls. At a speed of 26 miles an hour, he found it was $12\frac{2}{3}$ lbs., and at a speed of 19 miles an hour, 9 lbs. per ton.

Now, Count de Pambour states, as I have mentioned, that the *average* gross loads of the trains on the Liverpool and Manchester Railway, are 32 tons. This includes the luggage trains; we shall, therefore, be quite on the outside, if we estimate the passenger trains, which are the fast trains, at 25 tons gross each; we shall be also equally in their favour, and as much in excess in our estimate, if we set down their average speed at 25 miles an hour, and allow to it a retardation equal to 13 lbs. per ton. Then, as 25 miles an hour are equal to ten times the accepted speed of the ordinary steam engine, we must estimate the tractive power of a locomotive, under the given conditions, thus:

$$\frac{25 \times 13 \times 10}{150} = 21\tfrac{2}{3} \text{ horse power.}$$

This is all the power a locomotive exhibits in practice, under these circumstances; it is all the power the engine accounts for. The fact is, that the machinery of locomotives, at the higher speeds particularly, runs away for its first power. This will, I think appear evident, and well accounted for, when the nume-

rous and violent obstructing eddies which the stream must of necessity form in its passage through the pipes and steam chests down to the cylinders are considered; and also when it is recollected, that when the steam has arrived there, it has still to force its way through the narrow steam-ports or passages, while the pistons are quickly recoiling from it, and the slide or valve is moving to cut it off. Hence, if at each end of the stroke, the pistons can obtain from the steam the shortest impulse possible, they have got as much as can reasonably be expected. For every revolution of the driving wheels, each cylinder has to fill and empty twice; and, if any traveller on a railway will take out his watch, and count by it the number of the revolutions of the driving wheels—of the usual diameter of five feet—per minute, I think he will find them in practice to be, at a speed of 25 miles an hour, about 150 per minute, and 150 multiplied by four, makes 600 moves which the steam has to accomplish within that short interval. These are the causes of the lavish expenditure of steam and coke; this hurried work well accounts for the great throttling of the steam in the blast-pipe; this shows that the engine is, to a considerable per centage of power, working against itself; in fact, it is getting forward like a horse, panting and out of wind, who has nearly enough to do to carry himself, and has not time, while he hurries along, to recover his breath. When all these circumstances are borne in mind, I think it will not be considered, I have been guilty of the least exaggeration, when I have asserted, that the driving machinery of locomotives must, from the very arrangement of the engines, particularly at the higher speeds, recoil and run away from the first impelling power, before it has time to act profitably on that machinery.

But whether the tractive effort of a locomotive engine, at a speed of 25 miles an hour, and drawing 25 tons, be 800 lbs., as it is usually assumed, or 325 lbs. as the preceding data, borrowed from the work of M. de Pambour, and the lectures of Dr. Lardner, would appear to render much more probable, its whole available force will be found to be small indeed, when compared with that which is inherent in hydraulic propulsion. A locomotive exhibits, at its utmost capability, as respects an average speed, a tractive power of, say 325 lbs., while hydraulic propulsion, at the foot of the vertical column, shows, from figures, at the adjusted fixed

speed there allowed to it, a driving force of 85 cwt.; or, estimated in horse power, hydraulic propulsion at this point, exhibits for practical operation, a power of 693 horses, and a locomotive that of nearly 22 horses. Again, how does the question stand, when we come to the further extremity of a propulsion-pipe, where the hydraulic propulsive effect most be the weakest: here hydraulic propulsion shows a driving force (if, at this point, only under five atmospheres) of 980 lbs., or 8 cwt. 3 qrs., and the power of 71 horses, while, in the case of a locomotive, the figures will remain just as before, namely 325 lbs. tractive effort; being equal to a power of 22 horses nearly. The average effort of the hydraulic system, over the whole section of a propulsion-pipe, will be found equal to the gravitating power of 46 cwt. 3 qrs. 14 lbs. or to that of 382 horses. I think, however, that to form an estimate of the power of this system from an average effort, is liable to the very material objection, that the results so obtained will be insufficient; the grounds for which will be made to appear, as we pursue our inquiry into the mode of operation, and of the effect of the gravitating power of the vertical column, as soon as it is brought to act upon the piston; and which—having now by comparison, explained the exact position of the system at this point—we are about to resume.

As the figures, derived from sound—or, at any rate not too favourable data—show that the propelling force at the foot of the vertical column, acting through the travelling piston on the train, is equal to 693 horse power, it is clear to demonstration, that such an impulse must carry before it any string of carriages or trucks, that were ever linked together on a railway; and this, with perfect facility, and, in a manner, without effort. If they are at rest, it will start them without difficulty, and quickly run up the speed; if, on the contrary, the carriages are then at nearly the usual travelling velocity, it will restore all that is deficient in it, as soon as ever the sufficient opening of the communication valve permits this to be done without jerk, or roughness. But perhaps some of my readers may here wish to object, that this enormous propulsive agent decreases in power in a very rapid ratio. Most certainly it does, as I have already demonstrated. Hydraulic propulsion is of this nature: it will first fling into the train an *irresistible* momentum, limited in respect

of speed only by that velocity, for which the communication valve is regulated. This being effected, it only requires a maintaining power, similar to that exhibited in the locomotive system—say from three to seven cwt. and *probably in due proportion as the speed is high or low*—to keep the train at "full swing." It is for this reason, that I object to an average being struck between the initial and final power of hydraulic propulsion. I feel myself fully justified in claiming, as the available effort of the system, the first initial power, supported by a great maintaining force. But instead of such a maintaining power as the locomotive system exhibits, I have one which, commencing at 85 cwt. gives, at its least favourable point, a free propulsive force of 8 cwt. 3 qrs.! With *such* a power, a train will be thrown off from the end of the propulsion piping, with an amount of momentum in it, sufficient to bear it forward, with a very trifling loss of speed, for a considerable distance. At the same moment that this takes place, the driving column of water, being intercepted in its course up the propulsion-pipe by the closing of the stop valve, will shoot itself up the connecting piping, into one of the air vessels (S) which I have already alluded to. On throwing up the mouth valve, and entering such receptacle, it will be met by an inclined plane or curve in it, so arranged as to drive the propulsive current up, that it may—until the air pressure in the vessel becomes more condensed— exhaust its first force against the dome, instead of impinging violently against that side of the vessel, which would otherwise be opposed to it. But to return to the subject of the momentum; I shall require the aid of this force to drive the train only 150 yards, that is over the next alternating section of skeleton piping.

A heavy train, on the present locomotive system, cannot be stopped conveniently in less than a quarter of a mile; and then we hear the breaks creaking, to present all the obstruction of locked wheels, to the momentum, which otherwise would carry the train forward a considerable distance further. Now, if a train, with the small maintaining power at present upon it, exhibits so great an amount of progressive force, what impulsive effort will it be capable of exerting, when it borrows its momentum from a power so prodigious as that which I have attempted to describe; and which comprises the whole propulsive effort of an

inclosed, ponderous, current of water, under great pressure, and of considerable volume, shooting itself forward, with extreme velocity. It should be remembered also, that the larger and heavier the train, the more powerful its momentum becomes. This was several times well illustrated in Dr. Lardner's railway experiments, to which I have already alluded, where the heavier trains, under, otherwise like conditions, exhibited a much greater impulsive power in them, than those which were lighter. Hence, in hydraulic propulsion, heavy trains will be a convenience, rather than an incumbrance, to a system, which, as respects propulsive power, will be absolutely master of any weight, which can be compared with any thing, that ever ran before on iron rails.

CHAPTER V.

The exact ratio of the decrease of speed over a length of skeleton pipe, must now be inquired into; and, for determining this question, I am prepared to take such data as are already in being; but as these data are obtained from observed results on the locomotive system, it will, I trust, from all I have just urged, appear probable to many of my readers, that the inferences so obtained—though satisfactory as far as they go—will be insufficient in the present instance.

It appears that Dr. Lardner, while experimenting on the Liverpool and Manchester Railway, to determine the resistance to the trains in motion, undertook several experiments on the Sutton incline. In the course of one of these, mentioned in his second lecture, two coaches, weighted to the gross load of 11.33 tons, were brought to the top of that incline, and then suffered to descend by gravity. Now the Sutton incline is one in 89, and, according to M. De Pambour, 2,446 yards in length; and, at the foot of it, there is what may, for all practical purposes, be termed, a level, as it presents an incline only of one in 2,762, and which has a length of 4,241 yards. These coaches, in descending the incline by their own gravity, acquired a speed, the lecturer observed, of 28 miles and a fraction; and they ran, in all, a distance of 4,577 yards. Deducting from this, the length of the incline, it appears they were carried over 2,131 yards of level, by their momentum alone; their speed, at the commencement of this level, being, say 28 miles an hour; and their loss in velocity accordingly, being, at the end of the first 150 yards of level, at the rate of $1\frac{7}{8}$ miles an hour, as near as possible. This loss, then, I will allow for the passage of a train over a skeleton length of piping; and, deducting it from the final speed, $27\frac{1}{6}$, due to the end of a section of propulsion piping, I have for my final speed at the end of a section of skeleton, that of $25\frac{1}{4}$ miles an hour; and at this speed, it may be considered as entering the next propulsion-pipe.

The speed mentioned in the above experiment, as that due at the commencement of the level, is some trifle higher than the driving speed I *claim*—whatever I may conclude, for reasons previously stated, it will prove to be in hydraulic propulsion—but, as the load, in the experiment alluded to, was so much lighter than those, it would seem reasonable to work, under so powerful a system, it strikes me it would appear almost like affectation, were I to propose making any deduction of speed, on this score; particularly as the experiment, from which I deduce my calculations, does not appear to have been one of the most favourable for my purpose, of those which Dr. Lardner undertook; though it is one in which all the requisite data are most distinctly given.

The figures in the preceding pages will now enable us to determine what the average speed will be, on the hydraulic system thus arranged, over an extent of railway; and this is at once found to be 26½ miles an hour. If this very slight decline in speed, in producing an average, is worth consideration, it might easily—and where new railways were forming—economically, be avoided, by making each line a waiving one. It would be effected thus: let the gradiants usually be such, as that the trains shall ascend, along that part of a railway over which a section of propulsion-pipe extends, at the rate of, say one in 100, and descend at the rate of one in 200 over that, carrying a section of skeleton pipe; the gravity and momentum together, thus compensating, for the very trifling retardation, otherwise here experienced in the speed of a train. An ascent of one in 100, or even one in 50, I think it might easily be shown in figures—if I might further be allowed to detain my readers—would not sensibly affect the speed of a train over the propulsive piping, as the driving power there is so enormous. In fact, the gradients, which this system of propulsion would easily overcome, are of a character so dissimilar, in point of steepness from those we thus far ever have met with on railways, that I would rather leave it to others to describe them, than hazard the charge of exaggeration against this little pamphlet, by undertaking this on the present occasion. A calculation of this sort would be most simple. Deduct so much from the propelling power, as will be absorbed in meeting the retardation due to a given train at a given speed, and the

large remainder of the propulsive effect, may then be applied in overcoming the inclination of a train to gravitate on an incline. As the square of the speed up an unfavourable country, is reduced so, in like manner, and in like proportion, is the amount of propulsive effort, at the further extremity of a section of propulsion-piping, where the driving force has least available power, increased. A trifling decrease in speed, would here afford a great increase of power.

Hence, were it proposed, by the aid of hydraulic propulsion, to ascend what are termed "hill sides," if the speed were lowered a little, and also if the length of the sections of skeleton piping proportionally reduced, and those of the propulsion-piping equally increased—or, even in extreme cases, rendered continuous—can figures show, this could not be done? Deep cuttings might be altogether, or at the least, to a very considerable extent, dispensed with; and an immense amount might thus, in the first instance, be saved to shareholders, and ultimately to the public, by enabling the directors of railways to adopt a system of very moderate fares; and this again would re-act in favour of the shareholders, by, in all probability, much increasing the traffic.

In fact, the difficulty of rendering steep descents practicable and safe, would be greater on this system—as it would be on every other—than that of overcoming the ascents. No propulsive apparatus, of course, would be required for that line of the rails, which carried the descending train; and where the descent was not very considerable, the difficulty might be practically overcome, by the beautiful contrivance which is adopted in the celebrated Box tunnel, on the Great Western, near Bath; and in which, before such means were taken, the descent was found to be inconveniently steep. Where the descents were very rapid, it is possible the iron rails might be entirely dispensed with, and strong wooden longitudinal sleepers laid, in place of them, with deepish grooves cut in them, *to fit at the bottom, the vertical transverse section of the periphery of railway wheels*, and with steep slanting sides to such grooves. If this could be worked out in practice, it would oppose a very considerable friction to the progress of a train, which might otherwise gravitate too fast. When the wood had worn a little, such longitudinal wooden rails would be improved, as regards the object here in view, not deteriorated.

It must not, however, be supposed that I urge this idea with any decided confidence in its practicability. I merely offer it as suggestion; with the full hope that something better, for remedying the difficulty, as respects the extreme cases, which I have proposed, may occur to more able and experienced mechanists; and with this observation, I leave the matter entirely open to consideration.

We are now arrived at that point, in this treatise, where we can properly investigate the character and effect of the propulsion-receivers.

It has been already stated, that the friction or retardation will increase in hydraulic propulsion, as the square of the velocity. Hence, if the speed required were a low one, the lengths of propulsion-piping might be increased in a much larger proportion than would be at first, likely to occur to the mind; in fact, to parody the celebrated sentence of the great mechanician of antiquity, an hydrostatic philosopher of the present times, might truly exclaim, "Give me but time, and I will send the power of water, under a vertical head, in piping, from one end of a county to another."

But as one of the first desiderata in any railway system, is to overcome time as well as space, the laws of hydrostatics require that, to preserve velocity, the propulsion-pipes should be comparatively short; and it has only been by combining, under the requisite conditions, the apparently dissimilar action of two leading principles in hydrostatics—slowness and extended operation, and velocity and contracted operation—that I have felt myself enabled to offer to the public, a practical and powerful system of hydraulic propulsion.

From all that has preceded, it appears reasonable, that a propulsive-pipe should not be shorter than 50 yards, nor longer, for the higher speeds, than 100. Well, then, thus far I show a train practically driven over some 70 yards of propulsion-pipe, and about some two or three hundred more of skeleton pipe, and that is all. The great inquiry now comes:—Can this mode of action, by any manifest and simple means, be continued? This inquiry I answer by the following statement. The retardation of water in piping is very trifling indeed, when it travels at a slow speed; in fact, at last, it becomes a mere shadow, and may be called

nothing. Call this principle, then, into action, by placing by the side of the railway, at the end of the first section of skeleton piping, a wrought-iron air and water-tight receiver, of sufficient capacity to contain rather more than that volume of water, which would fill a section of propulsion-pipe, and, over that, a much larger volume of air, let this volume of air, which is to press on the water in the receiver, being there condensed by a small hand air-pump, or any other convenient apparatus—for the means of doing this are not material, as it would not be likely to require repeating—and let this condensation of the air be raised to a pressure of six atmospheres: let the space within the receiver, so occupied, be equal to five times that which contains in bulk, one section of propulsion water; that is, when the vessel is duly charged. Now, let the power, at the first power station, occupy itself, when it has nothing else to do, that is, when no train is passing, by throwing into this receiver—*slowly*, so as nearly to obviate friction—one propulsion section of water, through the medium of an extra pipe, of smaller bore, provided for this purpose. Let there be also a short pipe, connecting this receiver with one end of a section of propulsion-piping—just as would be the case at a first power station; let this pipe be of the same bore as the propulsion-piping—or it might advantageously be a little larger, if, at its junction with the propulsion-pipe, it presented a conical-shaped termination. Now, the propulsion receiver being duly "charged" with water, under a pressure of six atmospheres, open a valve in this connecting pipe, and what happens? The water in the receiver, instantly shoots up the propulsion-pipe, *under a pressure of six atmospheres.* Does it so continue to the end of the pipe? No. The space above the water in the receiver occupied by the compressed air, which, before the valve was opened, was equal to five volumes of the water now discharging, will, by that discharge, ultimately become equal to six such volumes; and the pressure, which, in the first instance, was 6×5 will then become 5×6. This alteration in the pressure will clearly be gradual, and the change will be complete, just as the communication valve in the connecting pipe, closes again, on the propulsion-pipe having received its due charge of water. This will render clear to every one, the propriety in working the propulsion-piping, of starting the water, as in the preceding pages I

have proposed, under six atmospheres, and of allowing the pressure gradually to fall, so as to become equal to five atmospheres, by the time the work is done.

There will be one occasional exception to this alteration from six to five atmospheres. It will obtain when the driving water for the section of the propulsion-pipe, contiguous to a first power station, is derived immediately from a vertical column of water, of six atmospheres—or rather $6\frac{1}{2}$, as I shall shortly have to explain—and without the intervention of a steam-engine, or any other machinery whatever, at such first power station. When this takes place, the pressure throughout will be $6\frac{1}{2}$ atmospheres; but this, as I think I have already clearly explained, cannot, and will not occasion any variety in the speed, when the communication valve and its machinery, has once been adjusted for producing throughout, the required uniform velocity. Indeed, frequently when this occurs, it may be turned to very beneficial account. The vertical heads of water now alluded to, can only be expected to be found in the vicinity of high grounds; and such localities are the places, where it would frequently prove equally convenient and economical, if very considerable inclines could be well overcome. This final pressure of $6\frac{1}{2}$ atmospheres, would, in all such cases, allow of the propulsion-piping being lengthened, so as to extend the driving effort, and still afford a final velocity of $27\frac{1}{6}$ miles an hour, while at the same time, it might overcome a very considerable incline; or should the incline be short and steep, like a hill, the propulsion-pipe might remain of the ordinary length, and, *preserving the speed*, the trains, by this extra power, might be lifted on to this higher level with no more *apparent* effort than a sloop is lifted, in a lock, from a lower to a higher level in a canal.

But to return to the propulsion-receiver. The capacity requisite to fulfil the preceding conditions, will be found to be amply provided for, if the receivers are made of a conical shape, of nine feet six inches diameter, and of twelve feet height in the cone or barrel, surmounted at the top by a half-spherical dome, and consequently measuring vertically through its centre, four feet nine inches, and finished at the bottom by a dome, measuring, in the same direction, two feet four and a half inches. They might advantageously be formed of thin wrought iron, if of $\frac{1}{4}$ to $\frac{5}{16}$ in

thickness, ($\frac{5}{16}$ being a strength frequently to be found in steam boilers,) they would—bearing in mind the form of the vessels —combine the character of great strength with lightness, which is material in a financial point of view; and, if lined inside with an adhesive *skin* of caoutchouc (India-rubber) of $\frac{1}{4}$ or $\frac{3}{8}$ of an inch in thickness, or even if coated inside with an asphalte cement, they would possess the characteristics of being perfectly air and water tight, and of great durability. These propulsion-receivers might, very properly, be neatly painted—blue with white belts, or white with blue belts, for instance—and when placed, as they would be, about one-eighth of a mile apart, along one side of a railway—they would not be required on both sides, for *one set would drive over both lines of rails*—they would present a very ornamental appearance, and break the too frequent monotony of confined railway prospects; and to this, their low foundations of brick or stone-work, would contribute.

I have, some pages back, supposed the case of a first power station occupied during one of the intervals in the passing of trains, in "charging" a single propulsion-receiver. This, however, would be the work only of two or three minutes, as I shall have occasion to show further on; and, besides, one propulsion-receiver would only constitute a medium for conveying and applying the propulsion force of a first power station, to a second section of propulsion-pipe, and thus, with the aid of the momentum of the train, over the contiguous length of skeleton. There must evidently be a series of the propulsion-receivers provided, which must extend along the railway on both sides—to the right and left—of the first power station, for a considerable distance, though only on one side of the line. In fact, the distance must be limited only by the number of propulsion-receivers, which the available force at the first power station shall, under given conditions, be found capable of charging during the intervals—arranged, of course with a view to regularity in time—between the passage of the trains.

It will be apparent that by an arrangement of this character, I am preparing to unite, for beneficial co-operation, the action of the two important laws in hydrostatics—which I mentioned some few pages back, as being dissimilar in their mode of operation—for the perfecting and completion of this mode of propulsion.

CHAPTER VI.

It is incumbent upon me now to show the number of propulsion-receivers, which a first power, of given amount, will be able to change during a given interval, between the passing of the trains; and which interval, would otherwise be one of absolute and profitless inaction. The power, which shall, for the present calculations, be assumed as acting at the first station, shall be one that would be least favourable for this system, namely, that of a steam engine. This steam engine we will suppose to be, on the Cornish pumping principle, and of 50 horse power. Now let us see what it will do; over what lengths of railway it will drive; and what intervals between the passing of the trains, for this work, it will require.

Such an engine of course, will be single acting, and work with a plunger or ram; that is, as a force-pump, not as a lifter. It must, as usual, be provided with a powerful air vessel, to keep the current of water running and charging the propulsion-receivers, during every alternate, or return stroke, when it is clear the engine itself, will not be acting on the liquid.

A 50 horse engine is a machine, which, after overcoming the friction of its own machinery = 7 lbs. per horse—shall be fully and easily capable of exerting a free power, equal to 150 lbs. (a horse power) multiplied by 50 (150 × 50 = 7500 lbs. = 66 cwt. 3 qrs. 24 lbs.) and of doing this, that is, of exerting this lifting, driving, or forcing power, at the rate, or—if taken longitudinally —over a space of 220 feet per minute. Now this machine must apply its power upon the propulsion-receivers, to charge them, through the medium of a pipe, which must run up one side of the line, under those vessels; and which, in the reference to the drawing, I have named the "receivers' feed-pipe."—I now beg to refer to the drawing and reference, as exhibiting this pipe, and propulsion-receiver, and also the valves belonging to this

part of the machinery; all of which will be found to be self-acting, and so arranged as to close of themselves, when one pair of receivers is charged, and at the same time also to open a further extent of the pipe, so as to allow water to pass on to the next, and so on consecutively, till the work is done. Then the engine will stop, resting on its load, till again called into action by the opening of the valves of the first pair of propulsion-receivers—for, as I shall have to explain, they will be replenished in pairs—allow it again to re-commence charging. Unless a railway had to carry over it an enormous traffic, there can be no occasion for providing a feed-pipe of a diameter anywise approaching that of the propulsion-piping; one of much less diameter will be fully capable of charging the propulsion-receivers, so as to drive a very wide traffic; and such a pipe will be economical, not only as regards its own dimensions and those of the valves, but also as not requiring so great a force as the first power station to work it.

It appears, that a diameter of seven inches (inside) will be a very convenient one for the receivers' feed-pipes, as it will provide sufficient capacity, without large dimensions or weight, and will present an area of as near as possible, one third that of the propulsion-pipes. Now, I have already stated, the line of propulsion-receivers on each side, or to the right and left hand of a first power station, is to be charged from the power there established; consequently, in the present case, the steam engine will be employed in charging two receivers, one on each side of it, at once. The engine, therefore, and its forcing machinery, must be of a capacity to work the water up two feed-pipes at the same time, *presenting together, an area of two thirds of that of the propulsion-pipes;* and I may add *only* two thirds; for, by this arrangement, we accomplish the feeding of the receivers by a power, only two thirds of that, which would have been required, if the area of the two feed-pipes, branching right and left from the first power station, had been together, equal to the area of a propulsion-pipe.

Before I proceed in my inquiry, into the working effect of a fifty horse engine, on a hydraulic railway, let me here remind my readers, that I have previously mentioned, I should occasionally require the aid of an extra half-atmosphere of pressure, at my first power station; and it is now that such will be requisite.

When a propulsion-receiver has delivered its charge, the superabundant pressure of the air within it, will be equal only to that of five atmospheres; *that* is the most favourable point for the present work of re-charging; but let us go to the least favourable, and suppose the same receiver is taking back its water, and has received very nearly its whole charge; it will then present an air-spring, opposing the ingress of the water, equal to a pressure of six atmospheres. If then, I had no more than the same pressure available at the first power station, one power, that of the steam engine or vertical column, (as the case might be) would be exactly counterbalanced by the other power or pressure, namely, that in the propulsion-receivers; and the work would consequently stop. The reason for preserving a constant available power of 6½ atmospheres in the machinery, at the first power stations, will now be most apparent; and it will also be clear that, this *constant* power will be required to overcome an opposing power, varying from five to six atmospheres—the length of time it will take in doing this, in the several circumstances, in which it will be required to accomplish it, will be minutely stated, a little further on.

Now, to preserve all the clearness and simplicity possible in these calculations, let us revert to the power, load, or pressure, which in a former part of this pamphlet, was found to be due under 6 atmospheres, to the area of the propulsion-pipe; then we will add to that power, the pressure and load due to the extra half atmosphere, (equal to 16½ feet of water, vertical) and of the amount so obtained, we will take two thirds, and set the same down as the free impulsive power, which, it has just been explained, the engine must exert. We shall then consider what proportion this power bears, with that we have already assigned to the engine, and so we shall pass on to determine the time it will take on each occasion to accomplish the work, which it will be required to perform.

The pressure, or available force of six atmospheres, upon an area of one foot, (that of the propulsion-pipe,) is 86 cwt. 2 qrs. 14 lbs.; to which, add the pressure of an extra half atmosphere, (7 cwt. 0 qrs. 24 lbs.), and we have, as the whole gravitating power of 6½ atmospheres, 93 cwt. 3 qrs. 10 lbs. Now, take ⅔ of this, and we shall find, 62 cwt. 2 qrs. 7 lbs. will be the free power

which I shall show the steam engine will be required to exert. This, in fact, represents the gravitating power of 6½ atmospheres of water, when pressing on an area, ⅜ that of the propulsion-pipe, and the engine will have to perform the work of such gravitating power; but it has already been shown that an engine of 50 horse power, exerts, with ease, at its ordinary work, a moving force equal to 66 cwt. 3 qrs. 24 lbs. There will, therefore, remain in the engine, unapplied, an amount of force equal to 403 lbs.—nearly three horse power; but as it is desirable that the machine should have a light, rather than a full load, I shall not propose to reduce the horse-power of the engine.

It now remains for us to consider, in connection with the present subject, the number of propulsion-receivers, such an engine can charge within a given interval; and this will give us the length of railway, over which such a machine will have to afford propulsive power to the water.

It appears a reasonable thing to assume, that a working railway day on any extensive line, will consist of 16 hours; and if the trains were large—as they might be advantageously on this system—the day traffic might probably, with very few exceptions, be performed conveniently with 24 trains. Now, this number of trains, divided over a space of 16 hours, would allow an interval of 40 minutes between the passing of each. Within such an interval then, the 50 horse engine must complete each series of its work. That series, I find, will comprise the charging of 19 propulsion-receivers; that is, nine on each side of the engine, and one immediately before it. This last will be requisite, as the engine itself will not force the water forward with anything like that velocity at which it must be worked. The engine will accumulate power comparatively slowly, and the propulsion-receivers, throw it forward at a great velocity; and this, for reasons already given, when referring to the action of two great laws in hydrostatics. The object in view, in the last named receiver, which would here stand immediately in front of the engine, may however, be obtained conveniently enough in the air vessel, through the agency of which, I have mentioned the engine will preserve a constant stream of water flowing up the receivers feed-pipes; this I now propose, shall act also as a propulsion-receiver. This receiver and air-vessel conjoined, therefore, has to become

the medium for accomplishing the work of a vertical column of water, if it had constituted the first moving force at that particular power station, both as respects, throwing the propulsion water up the adjoining driving pipe, and also, charging the receivers with a continuous stream, and which it will commence doing as soon as its preceding work is finished. The only point requiring attention, before this air vessel is set to do double work—though it can never have to perform both duties at the same time—is, as respects its capacity, in which it must be equal to the other receivers. It will, as the air vessel of the engine, be under sufficient pressure, and in that character also, it must be made of extra strength, say of wrought iron, of the full ordinary thickness for steam boilers, namely that of $\frac{3}{8}$ of an inch; for the water from the engine force-pump will enter it with a sort of rush or shock, very different from the regular stream in which, through this same vessel, it will be conveyed into the other propulsion-receivers.

The 50 horse engine, we are at present considering, will only be enabled to throw the water forward, up the two branches of such a feed-pipe, as that we suppose in connection with it, at the rate of 220 feet per minute—that being the average steam engine speed. But a propulsion-pipe contains 210 cylindrical feet of water, and as the area of the feed-pipe is only $\frac{1}{3}$ of that of a propulsion-pipe, this content of 210 feet of water will, in the latter case, be extended over three times that length, or 630 feet; and this is the length of the column of water of the reduced area, which the engine must throw into each of the receivers—charging a pair of them together, on account of the diminished area of the horizontal column—to constitute a full charge for each section of propulsion-pipe. Now, the lifting or forcing forward of any thing, which is a load for an engine, over a distance of 630 feet, is very nearly three minutes average work for such engine, and the *two* columns of water, which the engine has to throw up the feed-pipes, right and left of it, constitute such a load. Hence, if the retardation of the water in the feed-pipes was so far overcome, by the preponderation of the column of water, or an equivalent load, in favour of the engine, as to allow of the liquid being passed up these pipes at a much higher velocity, the engine could not, under the explained conditions, accomplish it. It would, however, be very different when these

receivers were charged from a vertical column of water; for that would be capable of almost any speed which the retardation would permit; and wherever such a column can be found, several of the receivers, which are least removed from the first power station, will be charged accordingly, much more quickly than by the engine. An engine, certainly, might be adjusted to do its work under a different arrangement; but the better method would be, not to increase the speed of the water, but the size of the feed-pipes; that is, if this were ever required; in either case, however, a proportionably increased engine power would be requisite.

Now, as I have stated that the engine must take as its load a double column of water, of seven inches in diameter, and force it up the two branches of the feed-pipe, it follows, as a steam engine can lift or push its load 660 feet in three minutes, that, appointing the engine in question to charge a pair of propulsion-receivers—being equidistant from it, on the right and left hand—with 630 longitudinal feet of such double column of water, would constitute a short three minutes work for the engine; provided its free action, at that speed, were not affected by any retardation in the pipes. Thus—bearing this process in mind—the engine, having to charge one propulsion-receiver standing directly in front of it, and nine pairs on each side of it, will be able to accomplish this series of work within thirty minutes. But this apparent result must be qualified in the following manner: first, the single receiver, taking, through a pipe of proper bore, the whole water, from the engine till its own charge is complete, will be charged in half the time that a pair would require, that is, in 1½ minutes—or something less, if we took the power of the machine at its full average working rate—next the six pairs, nearest the engine will be charged in the time just stated as due to the work ($6 + 3 = 18$) for the retardation due water travelling up to a pipe of seven inches bore, at the very low velocity of 220 feet per minute, is too small to retard the work within that length of pipe, which will reach to the sixth pair of receivers—each of which will be placed at a distance of 1,320 yards from the engine;—then, the seventh pair—220 yards further removed—will be charged in three minutes and 17 seconds; the eighth pair—220 yards further—in three minutes and 30 seconds; and lastly, by the ninth pair—220 yards more

distant—will be charged in three minutes and 37 seconds. These results are in exact accordance with Tredgold's formula. Wherever the retardation, under the preceding conditions, has been found to impair the given first speed, its effects are estimated by his rule; and, as in all previous cases, without claiming any acceleration for the momentum due to these extended moving columns of water.

To recapitulate the preceding results; we have—

	Min.	Sec.
One propulsion-receiver charged in	1	30
Six pairs of do. do. do	18	0
One do. do. do. do	3	17
One do. do. do. do	3	30
One do. do. do. do	3	41
Time required to charge propulsion-receivers for 2½ miles of rails	29	58

Thus, though I have made the preceding calculations, for the propulsion power being required about once in forty minutes, it appears highly probable that a 50 horse engine might drive a train over an extended length of railway, once every half hour, if there were occasion. The nature of the propulsive agent ensures great regularity as regards time, and the momentum of the very powerful columns of water, both in the propulsion and feed-pipes, appear very likely to cause all the work to be accomplished at a more rapid rate than I have, in this pamphlet, set forward in my calculations, as being due to it. Should any enormous amount of power, in considering future prospects, be thought desirable for any of the greater lines, feed-pipes of 9¼ inches diameter might be charged, for the length of line I have considered as under the action of each first power station, in 17 *minutes;* or the length of line acted upon by each power station, might be extended to three miles, when such feed-pipes would take 22 *minutes* to charge them; but pipes of this diameter would require a power equal to, from 70 to 75 horse, to work them with full effect. Before I dismiss this subject of speed, in its various proportions, I may here be allowed to allude to the present speed in the locomotive system, and to compare it with the anticipations on this subject before locomotive engines had been brought into great practical operation. Mr. N. Wood, in his celebrated "Practical Treatise on Railways," states that, in his

first edition of the work, in 1825, he mentioned that 40 tons conveyed six miles an hour, was then the performance of the best locomotives; and he adds, "in 1829, according to the table given by Messrs. Walker and Rastrick, they fixed 48½ tons, conveyed ten miles an hour, as the highest performance the directors of the Liverpool Railway could expect for their engines!"—*Third edition*, p. 547.

The length of railway over which 19 propulsion-receivers will drive the trains, is very easily estimated. Calculating from the centre one, there will be nine receivers on each side of it, with an interval between each of ⅛ of a mile; and a like interval will be found between the last receiver of one first power station, and the last one of the next: (see drawing); thus these 19 receivers will propel the trains over two miles and three-eights of the railway; and this not over one, but over both lines of rails; for with the exception of the propulsion and skeleton piping, and a few valves, &c. for the second line of rails, it will not occasion much more expense to establish this system of hydraulic propulsion on a double railway—one of the ordinary arrangement—than on a single one; which with a large traffic would be most inconvenient, if not absolutely impracticable. The same driving force at the first power stations, and the same propulsion-receivers and feed-pipes, with their valves, would do a very large amount of work on a double line, as well, and in fact with more facility, than on a single one; and, as respects propulsive effort, 2⅜ miles of double line, are equal to 4¾ of single line.

I believe I have not yet mentioned the night-work, which usually implies the passage of the luggage trains. Under the present system, these travel, from motives of economy, at a much slower speed than the passenger trains. Mr. Wood, in his work, estimates that a locomotive engine which, at 20 miles an hour, can drag 98¼ tons, at 30 miles an hour, will only draw 27 tons! With hydraulic propulsion, there would be no occasion for this great loss both of speed and time. From my estimate of the duration of a railway day, it will appear there are eight hours left for night; and within this interval, 12 luggage trains at least might be conveniently passed over a railway. I am not aware of any line that has to afford conveyance for this number of heavy

luggage trains nightly; there are, however, occasionally night mail trains; and these might take their share of propulsion among the rest.

It will be perceived, that in the latter pages of this little work, I have viewed the drawing power for the system, nearly as if the steam engine was the only source from which I could derive a first motion. This I have done for two reasons: first, it has been objected against hydraulic propulsion, that vertical heads of water of requisite altitude, will seldom be available. As regards many lines—or a considerable portion of them—I admit this objection in its full force; and as regards others, I admit it with two qualifications; the first is, that wherever railways now formed, pass under the spurs of hills, or through them by tunnels, there will be occasional opportunities, more or less frequent, according to circumstances, of taking advantage of good powerful heads of water, of at least $6\frac{1}{2}$ atmospheres, hydraulic altitude, —214 feet—and when they *can* be found, economy dictates their useful application; and that they will occur more frequently than might at first be imagined, appears probable enough, when we bear in mind, that those lower elevations, near which, railways occasionally pass, are frequently the abutments of higher hills; and without going a quarter of the distance, that water-works Companies sometimes fetch their water, when offered them under such inducements; and by the aid of supply receptacles, extremely small when compared with their dams, I cannot but think the quantity of power economically to be derived from such sources, will be very far from contemptible. My second qualification to the objection, is stronger still. It applies to lines that may be formed with a view to availing themselves of hydraulic power. These will naturally seek the vallies among the hills and mountains, and court the contiguity of high grounds, which elevations must often furnish abundant hydraulic power, to overcome with ease the undulation of the country, and to drive a large traffic at a very trifling cost indeed. I hardly need say, that there can be no binding necessity for the first power stations being distant from each other exactly $2\frac{5}{8}$ miles. Good falls of water would at any time, to a certain extent, influence their locality, and whenever one presented itself, any where between two and three miles from the last station,

would be fixed upon as the spot for the next. But whatever advantages may ultimately accrue to the system from such sources, the whole tenor of this pamphlet, I trust has made it apparent, that I do not consider hydraulic propulsion should look for that success which I think it deserves, mainly for the frequent aid of natural vertical heads of water; and this, particularly in the case of railways already formed. I think I have already shown, it has very great power independent of such aid; and it will remain for me, in the same circumstances, to prove its great economy.

I must now explain the second reason, for which I have latterly viewed the steam engine, as nearly the only first agent for charging the propulsion-receivers. It is this; the steam engine has become throughout the country so perfectly the popular representative of power, that when a working force has to be estimated, it is most conveniently done through the medium of this deservedly popular machine. But then it should, at the same time, never be forgotten that there are many other machines. Water wheels, Barker's mills, and those powerful water machines of the steam engine construction, as respects cylinder and valves, which bear the name of hydraulic engines, might all occasionally be brought in to aid the working out of this system, with powerful effect, and with a view to its most economical arrangement. A low fall of water, if of sufficient volume, will drive almost any hydraulic machine, so as to do the work of a steam engine, without the cost in fuel. To such an extent might this principle be sometimes carried on railways, as to cause one stream of water to do, in a manner double work. Thus, a stream conducted down from the head of a deep cutting, might first work a water-wheel, for instance, on the level of the railway; and, afterwards, the same stream of water might be conducted some distance, in a proper channel, along one side of the line, till brought to the top of a high embankment, down which it might be thrown upon a wheel beneath with considerable effect. The power from the water wheel, would, with much ease, be brought up again to the level of the railway, to be there applied upon a contiguous first power station: hence, many advantages may be expected to accrue to this system, which will not show themselves on the face of the calculations.

CHAPTER VII.

The apparatus for bringing hydraulic propulsion into a state of practical application on railways, is exhibited in the drawing; and a short description of it will be found in the reference to the figures. But to that description, it now seems desirable to add a few particulars, which could not conveniently be given there.

The continuous cleft in the propulsion-pipe, it will be observed, presents in section the outline of a truncated cone, being narrower at the top than the bottom. Hence, the continuous flexible valve will have a disposition to fall out of this cleft to the bottom of the pipe, when the water in the propulsion-pipe pressing it upwards, and holding it in the cleft, is drawn off: at the same time, the pressure, being so very great, may occasionally fix it there too firmly to allow of it falling out by its own weight, when the liquid has done its work, and has again been withdrawn. In either case, the machinery is arranged for the satisfactory action of the valve; if, as in the first instance, the continuous valve is found lying along the bottom of the pipe, as the travelling piston advances before the column of water, its guide-neck, with the long snout it presents in front, takes it up, and allowing it to slip between two guiding ridges, up the inclined plane which its back presents, passes it, in a manner *through* the connecting plate, before this plate is itself carried through the continuous cleft, in order to attach the train to it for the purpose of propulsion. This is effected by causing the plate to divide, arch-fashion, just before its junction with the guide-neck, thus affording through it, a free passage for the continuous valve. This valve is then slided over the forehead, or highest part of the incline, and so placed loosely in the cleft, before the piston itself passes; as this takes place, the water by which it is driven forward, on reaching the valve, pressing on its under surface, wedges it (I may almost express it) firmly into the cleft; and this with air-pressure, varying from 97½ lbs. to 75 lbs. on the

square inch there can be no doubt whatever that the pipe will be then perfectly water-tight; that, in fact, for the time being, it will be most effectually corked. Now, on account of this wedging of the valve, it is possible it may occasionally not fall down into the bottom of the pipe, as I have anticipated, even though the formation of the cleft is such, as to make it appear difficult for it to retain the valve, when a pressure underneath no longer exists. But, supposing this to take place, the machinery is also arranged to meet the contingency. The arrangement is most simple; it consists of two small pulley wheels, attached to the driving truck, and placed one before the other, a little in front of the power-connecting-plate, in such a manner as first to loosen the valve in the cleft, and then to put it down; when it will be in a most convenient position for sliding along the upper part of the guide-neck, and so taking its place in the cleft again above the piston.

The materials of which this continuous valve should be composed, and the manner of its formation, must be explained: and first of its formation: let it be done thus; form a mould, say of clay or plaster of Paris, whose transverse area shall be the same as that of the valve, to be constructed; and within this mould, before it is completed, stretch well apart, a series of small strands of wire rope, or strong single wires, longitudinally; then, transversely, fully half fill it in a systematic manner, with short and moderately thin bits of very hard wood or whalebone, of the same length as its transverse section, in the different parts of it, where the wood is placed. When all this is well arranged, the material for filling up the insterstices, only remains to be pointed out and applied; this is caoutchouc or India rubber; which in a liquid state, must be poured in, to fill the mould. It will now, therefore, be evident that the intention is to *cast* the continuous flexible valve in a mould. When dry, the valve is made and ready for use. The wire strands will prevent the continuous valve from stretching longitudinally; and the bits of wood or whalebone, will prevent it from contracting transversely, in any inconvenient degree, when subjected to the high pressure, which it will be required to sustain.

It will be observed, that a stout wire is made to stretch over a section of skeleton-pipe, just the same as the continuous valve

does. through one of the propulsion-pipes; in fact, the valve and rope, being always linked together, keep up one unbroken line. This is merely to preserve the connection between one section of continuous valve and another. The wire rope will consequently pass over the guide-neck and piston, as the train goes by, in the same manner, but more loosely, than the continuous valve itself does. The whole of this apparatus will require, before being put intouse, to be subjected to a great tension, to prevent after-stretching. It will then work with great truth, as there will be seldom where more than about seventy yards of the continuous valve, or 150 of the wire-rope, exposed at once to any draft or pulling from the travelling piston—small, though it will be—for each length of the continuous valve, when fixed in the cleft, by the water pressure under it, will be quite immoveable, and will constitute a strong holding power, which will not be wholly relaxed, till some time after the travelling piston has passed over the adjoining section of skeleton, and entered the next of propulsion-piping. The power-connection-plate should be two feet in breadth, and $\frac{3}{4}$ or one inch in thickness, which will leave nearly an inch play in the cleft, on each side of it. These proportions will combine great strength, without any inconvenient degree of thickness.

There is a peculiarity in the formation of the piston, which nearly obviates the whole of the friction, that might very naturally be supposed to be due to such an apparatus, when travelling within a confined space, at a speed of nearly thirty miles an hour. The piston must, of course, be formed of the best wrought-iron. This will allow of its being made with a view (comparatively) to lightness, particularly in the feather extending below, on each side of its guide-neck, without sacrificing that requisite degree of strength, which should distinguish the apparatus.

Now, no part of this iron piston ever touches the propulsion or skeleton pipes, up which it moves; some rings of leather, or India rubber, which are fastened down to it on one side and quite loose on the other, only coming in contact with the sides of the propulsion-pipe. The piston is supported vertically behind, by one pulley or friction wheel, and before, by a pair—between which the continuous valve passes; thus, in the vertical line, it is evident the piston cannot touch the piping, as, in fact,

it runs upon wheels within it. In this direction, however, it approaches nearest to the pipe at its forehead, just above the arch-way, through the power-connection plate; but, even here, it should be fully half an inch below the pipe. In the horizontal direction, it is protected from ever rubbing or drawing against the sides of the pipe, by another friction wheel, placed forward, to guide it as truly in that direction, as the others will in the vertical. This horizontal pulley wheel, it may be remarked, is placed, as well as the vertical pair, in the guide-neck; but this, in speaking in general terms, must be understood as included in the common designation of piston. Now, the piston itself, that is the latter barrel, or cone-formed portion of the apparatus, will, as may be perceived by the drawing, approach in no direction, within $1\frac{1}{4}$ or $1\frac{1}{2}$ inches of the sides of the pipe. This statement at once renders it incumbent on me to explain how its requisite water-tight quality will be obtained. A series of rings of leather, or of caoutchouc, of a breadth of about four inches, are to be well rivetted down to it on one side—that nearest the guide-neck—and on the other, are left perfectly free; thus, if a very powerful blast were blown up the pipe, behind the piston, three or four of the last of these rings would expand, or open on their loose sides, with which they would then press against the sides of the pipe, and, consequently, would intercept the current. The very same thing will occur when the propulsion water presses on them from behind, with this difference only, that, as the liquid will wet them, they will more effectually, and with more facility, prevent its pressing on further, than say, the fourth or fifth ring; or, if it ever should be getting a little more forward, the slight chatter, or quick, but almost imperceptible shaking of the apparatus, as it rushes on at a great velocity, will, very quickly, throw it back. The most easy way of imagining the working of these rings, and the manner they will be thrown open by the liquid is, by recalling to mind, the opening motion in the water, of the gills of a fish. I think this series of rings, say, of caoutchouc, may very properly be termed the piston-gills.

The nature of the preceding remarks will make it very clear, there can be no occasion to bore the propulsion-pipes. Let them be well cast, with plaster of Paris, or other good cores, and the boring of them would, I imagine, become a most super-

fluous expense. The amount of saving, in this respect, will be one of considerable moment, when the value of the finished pipe is compared with the cost, that would otherwise require to be expended on it.

The piston, as I have intimated previously in this pamphlet, has a protecting valve at that end, which is nearest to the water. It is placed there as an extra security against accidents, and might be dispensed with, as the travelling incline—on the truck—which opens the communication valve, can immediately be thrown out of gear, or rather slotted back, close up to the truck; when, as it would, miss the pulley for working the above valve, no supply of propulsion water would ensue. It is, however, within reach of possibility for it to happen, that stray cattle, or a deaf person, might be observed on the same line of rails, on which the train was running, almost immediately after a communication valve had been thrown into action, to furnish its supply for 70 yards; and, therefore, it is probably better to incur the small extra expense it will occasion, and to retain this valve; which has, for its object, to allow of the propulsion water being shot through the piston, instead of driving it before it. It is rather remarkable, that the apparatus to work this trifling valve, carries with it, probably, more the appearance of complication, than any other part of the machinery of this system. This arises from the valve itself, being necessarily placed behind the power-propulsion plate, while the rods, which are to open or close it, must also, of necessity, be carried out through the cleft in the propulsive-pipe before that plate, and be then turned back for the convenience of the driver of the train. This complication, however, will, I flatter myself, be found to be only so in appearance, and at first sight. If the line of rods belonging to this valve, are traced through, they will, I think, be found to be simple enough in their mode of action; and if, for a moment, *they are imagined as being away*, and the other, and far more important, part of the adjoining machinery be then examined, it will remain for my readers to decide, whether it possess those first characteristics of good mechanism, namely, simplicity and aptitude, for the object in view.

Attempts, which may be termed demoniac, have, on a few occasions, been made to cause the most frightful accidents on

railways. There are several instances of large blocks of wood, or huge masses of stone, having been laid on the rails with the avowed intention of overturning the trains; again, serious obstructions may be left on a railway accidentally.

Now, whether obstructions on a railway, occur from pure accident, or a most culpable negligence, or from a depravity of mind, much lower than the tone of feeling which belongs to the most degraded of the brute creation; and however unfrequent any of these things may be, still any party who proposes to make material alterations in the arrangements of railways, should be ready to show how he is prepared to obviate all obstructions, from whatever cause they may arise, at least, in so far, as his own machinery is concerned. Let it be supposed then, that any depraved and most wretched person threw a lump of iron, or any strongly obstructing substance in a propulsion-pipe; what would then occur; judging only of the machinery from what had been already explained? There would be a partial shock just as the momentum of the train snapped the iron straps, which attached the power-connection plate and piston to the large pair of strong springs under the truck; but after that, the train would proceed, as if nothing had happened, till its momentum was exhausted, and it came to a stand. The piston itself, however, would be seriously damaged, and a proportionate expense would be incurred in its repair. Now this expense might be easily much reduced, and the shock, which, otherwise would be felt through part of the train, might be so much lessened, as probably not to be materially perceptible, even in the travelling truck. It must be borne in mind, that the business of the piston is to push the train forward, not to pull. To give it any required capacity of pushing then, place a shoulder on the springs, against which the front end of that part of the top of the propulsion plate, which is strapped or bolted to them, shall abut firmly. This simple contrivance will afford any ability for pushing a train forward, that may be required. Then let the iron straps, which, with the bolts, attach the connecting plate to the springs, be, comparatively speaking, slight; when, if any serious obstruction were incountered by the travelling piston, the straps should break; and, without any great shock, or materially damaging it, the piston

would become disengaged from the truck, and be left behind. The same principle also might be carried out in the small rods of the piston valve, through the medium of their joints, &c. The main part of the evil, if the circumstance alluded to ever occurred, would be then comprised in that of the mere partial delay, which must arise in procuring and attaching another piston.

Of the valves, not much need be added, to what has been said in the preceding sheets, and the mention made of them, in the reference to the drawing. The interception valve, in the drawing, is represented as closed. It is, I believe, in the ordinary acceptation of the term, self-acting; that is, it works from the ordinary action of the water in which it is immersed, without any extraneous guiding power being applied. It is placed in the junction of the curved pipe—from the first power-station, or from a propulsion-receiver—with the driving pipe. When down, this valve, with its two leaves, hangs in the way of the free passage of the swift current of water, which ensues as soon as the communication valve is partially thrown open. This current will throw the valve up, and, through the instrumentality of its two leaves, must retain it firmly closed, while the current and its great amount of pressure, remain. As soon as these are cut off, the valve falls again by the preponderance of its own gravity, and opens a way for the water to discharge itself from the large spout-like termination* of this end of the propulsion-pipe, into the mouth, properly arranged, of a drain for the purpose. To aid the gravitating power of the valve in opening quickly, its box and seat are, as will be observed, a little inclined in the direction, in which it has to fall. It will occasionally happen that the discharge of the propulsion water must be made at the other end of the pipe; that is, when there is a slight incline in that direction, say one in 200; for when one occurs, that is at all material, no propulsion machinery will be required for that line of rails, which leads down it. In all such cases then, where the discharge of the water must take place at the further end of the propulsion-pipe, the proportions of the loads and arrangements for

* This spout, in the drawing, is shown at the other end of the propulsion-pipe; but it will be more frequently at the end, above intimated, as the inclination of the pipe will usually be in that direction.

the quick, or tardy opening of the communication, and the stop-valves will be reversed. The seat of the communication valve, if inclined at all, will then be in the other direction, and its projecting leaf, which is to assist in throwing the valve up, will be made lighter, so that the mere pressure of the horizontal column of water of one foot in height—when the great vertical supply or pressure has been cut off—shall hold the valve to its seat for a short interval, while the stop valve, with (in that case) a greater gravitating power in it, shall be thrown open, and the water, be proceeding to discharge itself at that end of the pipe. This discharged water will frequently be allowed to run to waste; but where the supply is not superabundant, and where a steam engine, or other machinery, is fixed at a first power station, it will be occasionally run back thither, either through the drains already formed on the railways, to keep them dry, or through other short ones, to be added for this express purpose.

The globe valves of the air-vessels will be also found to be self-acting; and will discharge the water, shot up into these vessels from the propulsion-pipes, very gently into any channels that may be arranged for conducting it away. The two valves, connected with each of the propulsion-receivers, will be found to be also of the same character; being self-acting, through the same simple medium, namely that of the floating globe; and they are arranged with a stirrup, in order to open and close quickly; that is, towards the end of every up or down move of the floating globe on its lever, as it rises and falls with the water. This will be found to be desirable for the proper working of the engine, whenever that machine constitutes the first acting power.

I may here mention, that the man-holes in the air-vessels and propulsion-receivers, which, in the drawing, are represented as opening outwardly, should in practice open inwardly, to render the air-pressure in those vessels available, towards the perfect closing of these man-holes.

The air-valve in the propulsion-pipe, will be only required in case it is found the continuous flexible valve does not always fall to the bottom of the driving-pipe, when the water is drawn off. In that case, this valve, will permit the free discharge of the air, which otherwise would, as the piston advanced, become compressed in the pipe—from its being then closed in front, by the

flexible valve—until it might, eventually, even stop the train. But whether this valve will be found in practice, to be requisite or not, its pulley and leverage will be always required; as they also act, through the long connecting rod, which is exhibited as broken off, in the drawing, as reversing machinery for the communication valve. The leverage of this air-valve takes, through its pulley, a rise of eight inches, which it derives from the inclined plane on the driving truck; and it conveys this movement forward—multiplied by the relative proportions of the two arms of its bell-crank—to the communication valve, which—by its action being reversed—it closes with a fall of 14 inches.

The stop-valve, at the further end of a propulsion section, to arrest the progress of the water up that pipe, and turn it into the air-vessel, is to be closed, as it will be observed, by a traddle. This traddle is worked by the front pair of pulley-wheels, carrying the travelling piston; it has a shallow bed or recess in the bottom of the skeleton piping, where it is placed, and into which it falls, when the pair of pulleys throw it down; and, in doing this, throw up the stop-valve. The length of this traddle is three feet six inches; its fall is seven inches, and the lift, carried through the leverage of its bell-cranks upon the stop-valve, is 14 inches; being the full rise of that valve. The traddle will require its seat placing at such a distance in the skeleton, from the stop-valve, as may allow of the piston having wholly passed through, before this traddle begins to act. It has been before explained, that the stop-valve will, by its own gravity, fall, and thus again open the end of the propulsion-pipe—which it is only required to hold closed, while the propulsion-current is rushing up and exhausting itself in the air-vessel—as soon as the tide is turned, as I must beg leave to express it, and the water is drawing off. Now, while I feel the conviction strongly, that the machinery of this valve and the arrangement of its gravity, are good, and fully trustworthy for general purposes; yet I must admit, this valve does not possess that unerring certainty of action, which, I feel assured, attaches to the machinery of the interception valve: I admit too, that all railway machinery should be—as far as human foresight can make it so—quite unerring in its action.

Fully to entitle the machinery of this stop valve to that cha-

racter, I propose to add to it an additional lever, *solely* to guard against the possibility of the valve sticking to its seat, when the pressure of the water against it is withdrawn, and of its not falling by its own gravity, as it then ought to do. The lever and stirrup, which are to accomplish this, will move backward and forward in the space between the air and stop valves, as the machinery to which they are connected, guides them, and neither doing good nor harm, unless the very remote possibility, on which we are now calculating, of the stop-valve having adhered to its seat, should actually take place, when this leverage will certainly, throw it down, and open the orifice, or area, of the propulsion-pipe, which it closes. I have not arranged this lever for exhibiting any great degree of strength; for a very slight force would manifestly throw the stop-valve down, *if* it ever stuck: for the same reason I have consented to place the lever rather obliquely, with reference to its line of work, one of its arms reaching under the skeleton pipe, and the other, the outside of the rail, in the same line with that of the bell-crank lever of the air-valve. If either the proportion of strength assigned to this lever, or its relative position, is objected to, nothing can be clearer than that a little more metal can be worked up in it; or that, by lengthening its axis till it assume the shape outwardly of a thick short pipe, and by separating its two arms—so that one shall be attached to each end of that axis—any degree of strength, and strict engineering accuracy of arrangement, can be given to this precautionary machinery; the difference being only, that it will occasion a little extra cost, but not much; and, probably, without occasion.

The mode of passing a train from one railway to another, at the junctions, and from one line of rails to another, at the crossings, will require a little explanation; and it will be the more easily given, as the same principle is in operation on both occasions.

The skeleton piping will afford to the hydraulic system great facilities at such places, which will always require to be passed over on a section of that description, where the propulsive water never comes; and the laying down and proportioning the propulsion and skeleton piping, on a railway—by small additions to, or subtractions from, the respective lengths which any given

locality might otherwise prescribe for these pipes—so that a section of much more than the average length shall terminate at a crossing, or immediately beyond it, could never be lost sight of by an engineer. It will require a considerable section of line, beyond the last propulsion-pipe, to allow the impetus, then in the train, to die away, and the speed to be reduced to that, which is usually esteemed safe and proper; particularly at the short crossings, adjoining stations. Sections of skeleton, to terminate at, or near such localities should be at least 300 yards in length, except where an incline is interposed, of sufficient gradients, materially to reduce the speed of an approaching train.

When two lines of rails meet, at junctions, crossings, or sidings, a train on the locomotive system, is enabled, by the proper adjustment of the switches, to pass on to either; but this requires a man being constantly stationed on the spot, to work those switches, or points. This individual would be a very useful person on an hydraulic line, as not only the switches would require fixing—which employment occupies usually but a very small portion of his time—but also *the junctions of the wire rope;* which rope, as it is to extend along each section of skeleton, must evidently join, where there is a junction of pipes and rails. These junctions of rope are easily to be effected. At the end of one portion of the rope, at the junction, make a loop, and fortify it against friction, by having previously wrapped the rope with a strong iron wire strand: at the end of the other portion of the rope, attach a long narrow hook, shaped nearly like a loop; that is, with the end bent down till it nearly meets the shank, and only affording sufficient opening for detaching it from the loop, on the previously mentioned portion of the rope. Now, for the present, let it be supposed, this rope extends along the straight line of rails—not the crossing. Let it be also supposed there may be some occasion for here dividing the rope. In that case, the man, who has to do this, must be provided with a strong instrument, shaped like a pair of the largest garden shears; but which, at the end of each of the shorter arms of this double lever, must present two fingers, or bent fangs, to take the wire rope between them, and so as to clasp each end of it, where the loop and the hook on it, give an increased thickness. With this instrument, the man must draw the two portions of the stretched

rope a little nearer together, which would loose it at the junction; and who then would be enabled, with much facility, to detach the hook from the loop. Now, instead of *one* such hook, let us suppose there are two attached to the loop; that is, the one we have already supposed as belonging to the straight line of rails, and another, which we must now imagine as terminating the end of the wire rope, belonging to the skeleton pipe of the crossing, and here joining that which we have been previously considering. The man here in charge of the line, would merely have to detach the loop of that part of the rope, which belonged to that branch of the line, for which he was about to set the switches for the train not to run on, and his work would be done—or rather, nearly done; for the detached portion of the rope would require to be kept in a sufficient, moderate state of tention, for the convenience of afterwards attaching it again. This would be immediately accomplished, by affixing it to one end of a moveable stout double hook or S, the other end of which, would be temporarily held in any proper opening, cut into the skeleton-pipe for that purpose: or a moveable bracket might be easily contrived to answer the same purpose as this double hook.

In the previous remarks, on joining the wire ropes, it must be clearly understood, that, the loop and hook must not be too large together, to pass with the greatest ease, through the small archway, rising out of the guide-neck of the travelling piston. As iron is the only material to be used, which combines great tenacity with smallness in bulk, this will be arranged without any difficulty.

There is one point, at which the nice adjusting of the wire rope, between tension and laxity, may require practical experience for its perfect arrangement; and that is, at the short slidings and crossings which are frequently to be met with, at the stations, particularly the larger ones. The rope in such cases, will not lie stretched along the middle of the skeleton pipe, as it ought to do, for its being taken up with perfect facility, by the guide-neck of the piston; on the contrary, it will lie along the bottom, inclined a trifle from the centre, and bending a little towards that side of the pipe, next the inside of the curve. But, as at all such crossings the speed is low, there will be little or no difficulty to be encountered. It will be only necessary, as above intimated,

to adjust the rope to the circumstances of the case. Easing it there a little more than would be desirable for the higher speeds, is what would be required. As regards the curves, which occur on those parts of the lines, where the higher speeds are used, they present such very wide sweeps as generally to be imperceptible to the eye, unless it trace them into the distance. The inclination of the wire rope, therefore from the middle of the bottom of the skeleton pipe, over an extent—so very small, comparatively with the curve—as that of only 150 yards, would be very nearly as nothing; and the very slight side friction that would occur, in the wire rope sliding up the guide-neck and through the archway on the piston, would be fully compensated by the rope always having a tendency to draw the driving truck true to the middle of the rails, and not leaving in it a disposition to run off, on the outside of the curve, as occurs with locomotives, and occasions much friction, with a certain degree of risk.

During strong frosts plain water would not answer for propulsion purposes; it would freeze; but if impregnated with salt, and made into a brine, it would never congeal by any fall of temperature, known in this climate. From this no material expense would arise, as the brine would be run back again to the power stations, just the same as plain water would at other seasons; that is, by a very simple arrangement of drains. From these stations it might be worked over and over again, with small additions for loss by leakage, while the frost lasted. A weak brine would be sufficient to resist the congealing power of any ordinary frost; but were it even requisite, fully to saturate the water with salt, it would be nowise material, since the duty has been taken off that very useful article. The wise policy, which dictated that measure, has restored the natural order of things in respect of this substance; which is not only one of the most useful in domestic life, and several of the arts, but now is also one of the very cheapest. After becoming the material, for the skilful working of which extensive trades have been established, it appears not improbable it may extend its usefulness a step further, and successfully aid hydraulic railway propulsion at seasons when all steam locomotion is thrown into a state of the greatest confusion, if not helplessness, by

the severity of the water. Thus, when the driving-wheels of a locomotive engine cannot bite the rail, and whirl round, with the greatest rapidity, without advancing, the hydraulic system —assisted, instead of being retarded, by the hard ice on the rails, which will give a finer surface—will, with brine in its pipes, be enabled to preserve as much regularity in the time of the arrival of its trains and mails, as during the finest weather. In short, the hydraulic system is not likely to know anything of the seasons; it will not be affected in its operations by them.

CHAPTER VIII.

It is time I hastened to draw this pamphlet towards its conclusion. I think I have said enough, not only to demonstrate the practicability of hydraulic propulsion on railways, but also, to show that its application on them would be attended with a great encrease of driving power; and now, when I have made an estimate of the first cost of establishing this system of propulsion on a railway, and also of the annual cost of working it afterwards, my undertaking will be nearly completed. I think I shall then have done my duty to the public. Beyond a certain extent, the public cannot expect even a patentee to go; and, in justice, they ought not; for if an invention—particularly, if of magnitude—becomes successful, it is not to the patentee, but to the public usually, that the lion's share of the advantage falls.

I have, in a previous part of the pamphlet, proposed, that each first-power-station shall work both lines of rails, over an extent of railway, two miles and three-eighths in length. I have also proposed to use steam wherever water power is not to be found; and, I have intimated that on many lines, I should find it necessary, frequently to have recourse to steam. I shall now, under these conditions, proceed with my calculation of the first cost of laying down, on $2\frac{3}{8}$ miles of railway, the whole of the hydraulic machinery, necessary for working that distance. I shall also, to be on the safe side, assume that such part of any given railway, must be worked by a steam engine. Wherever a locality occurred, which was favourable for a supply of water, the difference between the expense of a steam engine, and that of the piping to bring down the vertical column of water, or of hydraulic machinery, if the head of water had not an elevation of 214 feet, would be easily estimated; and that, according to the circumstances of each particular case. In like manner, nothing will be more simple, if it should be desired, than to ascertain the first cost of any part of the apparatus, enumerated in the following calculation, for one mile of railway. It will be only requisite to take $\frac{8}{19}$ of the sum charged against it.

Calculation of the first cost of establishing hydraulic propulsion over 2⅜ miles of railway.

	£	s.	d.
Steam Engine, of Cornish construction of 50 horse power, with boilers complete, at £23 per horse.........	£1150	0	0
Engine house, with foundations and chimney, complete	350	0	0
Propulsion-piping, for 38 sections, of 70 yards each (including both lines of rails) of twelve-inch bore, and one inch in thickness, with girths and holdfasts placed every four feet; say gross weight per yard 4 cwt. 2 qrs. 20 lbs., at 7s. per cwt.; then 38 × 70 × 4.2.20 × 7s. =	4352	5	0
Branch-connecting pipes from first-power-stations and propulsion-receivers for the above; say average, for both lines of rails, $\frac{1}{7}$ the first cost of the above	622	0	0
Skeleton-piping (half-piping, with longitudinal openings along its sides) for 38 sections of 150 yards each, for the pulley wheels of the travelling piston to run upon; say ⅝ in thickness, and of gross weight of 1 cwt. 2 qrs. 0 lbs. per yard, complete; then 38 × 50 × 1. 2.0 × 7s. =...	2992	10	0
Propulsion-receivers feed-pipes of seven inches bore, and ¾ inches in thickness, for 2¼ miles (3,960 yards) ⅛ of a mile in each first power division of a railway (*i. e.* the space between one division and another) not requiring this piping. This piping complete will weight 1 cwt. 2 qrs. 17 lbs. per yard; then 3960 × 1.2.17 × 7s. =...................................	2289	7	6
Two travelling pistons with guide-necks, of the best wrought iron, together, 8 cwt. 0 qrs. 0 lbs. at £3. 10s. per cwt.	28	0	0
Two pairs of springs, with power-connection-plates and iron straps or shackles, for connecting the above named pistons with driving trucks. (N.B. Driving trucks are not charged in this estimate, as they carry loads, the same as other trucks)	50	0	0
Two Travelling inclines, for two driving trucks, with stays to slot and levers, weight of each complete, 2 cwt. 2 qrs. 0 lb., say 5 cwt. 0 qrs. 0 lb., at £2. 10s. per cwt.	12	10	0
Two piston valves, with motion rods.	16	0	0
Valve machinery for thirty-eight sections of propulsion-pipe; say for each section, machinery £46., and four valves and boxes £24., therefore 70 × 38 ...	2660	0	0
Continuous flexible valve for each section of propulsion-pipe, £10. 10s.; and wire rope for each section of skeleton £2. 10., therefore 10 10 + 2 10 × 38.........	494	0	0
Jointing and fixing pipes, and putting down machinery per mile, £240; therefore, for 2⅜ miles	570	0	0
Carried forward............	£15,586	12	6

	£	s.	d.
Brought forward...........£	15,586	12	6
Allow for bolts, and sundries in general, per mile £200; therefore, $2\frac{3}{8}$ miles	475	0	0
Propulsion receivers, weighing three tons each, say, with floating globe, &c., £60 each, therefore, 19 × 60	1140	0	0
Air vessels, about 9 cwt each, say, with branch pipes to them, and floating globes, &c., £25. each. Now there will be one of these required for every section of propulsion pipes, on each line of rails; and not, as in the case of the propulsion receivers, one, to feed two sections, that is, to work both lines of rails; therefore 38 × 25	950	0	0
Expense of establishing Hydraulic Propulsion, on a Railway, $2\frac{3}{8}$ miles, in length, for both lines of Rails£	18,151	12	6
Hence the gross first cost for one mile of railway may be taken at	7642	0	0

But from this gross first-cost, deduct the value of the valves, and air vessels, and the difference between the value of the propulsion pipe, and continuous valve, and that of the skeleton pipe and wire rope, on so much of each line of railway, in every mile, as this alteration would apply to, from the inclines being favourable, and the trains, with the aid of the momentum in them, being able to descend without any decrease in speed.—(N.B. Over such portions of the rails, the skeleton piping and wire rope, only would be wanted.)—On Railways already established, this deduction would not often be very large in amount. On Railways, to be established for Hydraulic propulsion, it would be very considerable, as the distance to which it would apply, probably would frequently be equal to one third of the cost of the whole line.

Deduct for diminished weight of rails, in consequence of locomotive engines and tenders—which comprise an immense load within a contracted length of rail—being dispensed with, and the weight of the trains being spread evenly over a sufficient length of the line. This will probably effect a saving of, from £400. to £500. per mile, as in the atmospheric system.

Deduct, for diminished height of tunnels, in consequence of their present extra elevation to allow the chimney of the locomotives to pass, not being required: deduct also, for diminished height of bridges over the line, and adjoining earthworks.

The figures, for the three preceeding deductions, claimed at the foot of the estimate, are not drawn out. They will differ with circumstances; and, as respects the first, the difference will comprise the widest range, from very moderate amounts, to those of the very first importance and the heaviest sums. On the whole, therefore, I have thought it best, for the present, to leave these matters in the position, to which I have now advanced them.

It will remain for engineers to say whether this estimate is a fair one or not; but, for my own part, I certainly do anticipate that many individuals of engineering ability, will be of opinion that some of the preceding items are overrated,

However, *when, over the whole of any given extent of railway there are no favourable inclines for gravitating*, it appears that hydraulic propulsion will cost—*supposing always that the rails remained of the present weight*, and that the first force or load on the propulsive water must be *obtained from steam and in no case from hydraulic pressure or power*—the sum of £7,642 per mile, *for both lines of rails*.*

The public in general may possibly require some standard of comparison to enable them to form an opinion as to the reasonableness, or otherwise, of the above first cost. I must therefore mention, that the patentees of the atmospheric system have very recently contracted with the Dublin and Kingston Company, to extend their railway to Dalkey (which, from the joint report of Sir Frederick Smith and Professor Barlow, on the atmospheric railway system, appears to comprise one mile and three quarters in extent) for £11,000; agreeing to forfeit £2,500 of this sum, if the undertaking does not succeed. I must add that this is for one line of rails only; and that a steam engine of 100 horse power is to be put down to work the line under these conditions. Thus it appears, that the first cost of the atmospheric principle is, per mile, £6,282, for a single line of rails.

I must now consider the annual expense of working a mile of railway by hydraulic propulsion. Whenever the propulsive force can be obtained, at a first-power-station, from a fall of water, whether it be of a sufficient altitude to afford a vertical column of 214 feet, or whether it must be rendered available through the medium of hydraulic machinery, the annual cost will become

* See Note F.

literally a mere trifle. In localities where this hydraulic first power is not attainable, the cost will arise principally from the expense of working—every 2⅜ miles—a steam engine of fifty horse power; that proportion of such annual cost as will be required to furnish power to the extent of railway, under consideration (one mile) being charged to it accordingly. Now a Cornish steam engine consumes 2½ lbs. of coals per horse power per hour. But the stationary engines of an hydraulic railway would seldom or never continue working the whole twenty-four hours round; probably half the time of steady work, would be as much as would be required. For present purposes however, I will assume, that the engine, the annual charge of which we are considering, does work, without intermission, both day and night, and the week round; which will make room for all casual charges, including tallow and oil for lubricating the machinery. I will further assume that the average cost, throughout the country, of a ton of engine coal, is ten shillings, which I imagine will be found to be decidedly in excess. Hence the engine must be charged with 1 ton. 4 cwt. 0 qr. 12 lbs., of coal per day of twenty-four hours, which must be considered as worth twelve shillings; thus, 12×365 gives £219., as the annual expense of working such an engine, to furnish propulsive power for 2⅜ miles of railway. Consequently, the cost of propulsive power for one mile will be £92.; that is, when this has to be derived from steam, and not from hydraulic pressure.

The wear and tear of hydraulic machinery will be extremely light; the whole of it, with the exception of the gills of the travelling piston, assuming the character of great durability: this applies, in a wide acceptation of the term, even to the continuous valve; for when at last its toughness gives way, and it begins to wear, the materials of which it is composed, will merely require separating, by melting the india rubber off; and with the same materials—with a little additional india rubber, for what has been worn away, a new valve will be cast. Consequently, if the annual wear and tear of the hydraulic system is taken at £50. a mile, it will probably be amply sufficient.

As respects the annual change of "Maintenance of the Way," —not accepting this term, at present, in its widest sense in which

it would comprise the locomotive or hydraulic departments of their respective systems—it is to be presumed that, in the system I advocate, it will be similar in amount, with that of the present steam locomotion railways; consequently it will not require taking into account in these calculations. In one respect indeed, hydraulic propulsion will cause a small addition to this charge; namely, for occasional small repairs for leakage of the pipes in the joints, &c. but in another respect, it will effect a material saving; namely, in the constant wear and tear, and breaking of the rails, and re-setting of the stone blocks and sleepers. The ponderous locomotives are a source of great expense, under the above heads; many of them, when loaded, weigh 14 tons and upwards, and a large portion of this load is thrown upon the rails through one pair of wheels only; namely, the driving pair; and the heavy tenders follow up the evil, the engines have begun, and no doubt often complete the mischief. But on an hydraulic railway, the travelling load will be fairly spread through the whole train; and an immense weight can never be concentrated on one, two, or three pairs of wheels, as must occur with locomotives. Therefore the profit being placed against the loss, the maintenance of the way, as respects the hydraulic system will remain the same as before—or, if anything, will be a little in favour of hydraulic propulsion.

To pursue the subject of the annual expense of this system for one mile of railway—and to do this, with a view of comparing it with the cost of steam locomotion—it appears, from what has preceded, that this annual expense will be £142. per mile; or let it be put down, in round figures, and on the safe side, at £150. To this must, in certain cases, be added, the interest of the first cost of the machinery, the laying of it down, and of completely establishing it on the line. The principal sum of this interest, I have shown to be £7,642; but from this account I have claimed deductions, which I think will fully authorize me in taking the interest now in question, at £300. per annum; thus making the whole annual cost of hydraulic propulsion, for one mile of way, £450. Now, what is the annual cost of steam locomotion per mile? M. de Pambour in the second edition of his Practical Treatise on Locomotive Engines, states at page 562, that the annual expense of locomotive

power, on the Liverpool and Manchester Railway, was, in 1834, £29,607. 5s. 11d.; being fully equal to £1,000. per mile, for the distance the engines travel over, on that line. I have some reason to think, this expense is now considerably higher; and it has been intimated to me, that I might adduce other instances, and from large railways, which would exhibit an annual charge for locomotive power, of still more serious amount; but I must hasten to bring this pamphlet to a conclusion.* Thus, *taking the figures as they, at present, stand*, hydraulic propulsion would cost £450 per mile, where steam locomotion costs £1,000! But either an addition must be made to the charges of steam locomotion, or—for the sake of producing a correct *comparative* estimate—a deduction must be made from that of hydraulic propulsion; tor as I have debited hydraulic propulsion with interest on the whole probable first cost of establishing it; in like manner, steam locomotion must be charged with interest on the whole first cost of the large and extensive workshops, valuable machinery, and great establishments peculiar to the locomotive system; or otherwise the annual expense of hydraulic propulsion, must be reduced by that amount, whatever it may be. I may here observe, that these workshops might be let or sold, on lines, where they are already established, which might adopt the hydraulic system.

It must be remembered, we are now debating the character and aspect of *comparative* estimates; therefore, while I fully admit the propriety of charging the interest of the first cost of hydraulic propulsion, to that system annually, when comparing its expense, with that of steam locomotion on railways already formed, I must strongly object to any charge, and I must claim a large profit, for hydraulic propulsion on this head, with respect to any railway to be formed expressly for it; for the saving of expense, in dispensing with deep cuttings and low gradients, and by seeking moderate undulations as much as, on

* I must apologize to my readers for any seeming hurry there may be, in getting through the subject of this little work, in the latter part of it. I have been advised, by my friends, to get this pamphlet into circulation, during the present meeting in this town, of the British Association; and it will be only, by the greatest effort, that this will be accomplished. If any errors have in consequence crept in, I sincerely apologize: but I greatly hope, that the statements in it, as far as they go, will be found correct and trustworthy.

the present system, they are, and must be avoided, *would swallow up, on any new line, the whole first cost of establishing Hydraulic propulsion; and effect, a saving most important in amount, besides.* Practical railway engineers will comprehend, in its full extent, the meaning of this observation. Nothing would gratify me more than to obtain, from one of those gentlemen, an estimate of the expense of establishing a railway over any line of country—particularly if it embraced that character, which, in railway phraseology, is termed, "difficult,"—first, for locomotive power, with such gradients as, to that power, are "practical;" and then for hydràulic propulsion, with those much steeper gradients, which, properly managed, will rather contribute to than detract from its efficacy. The difference, I imagine, would be full one half; that is, where a railway now costs £30,000. per mile, it would then cost £15,000.; but I state this deferentially, and, as the result merely, of such information as may be acquired from popular and general remark; for, it is not in my province, but in that of the distinguished body of railway engineers, to state with confidence the difference in the first costs between establishing any new railway for locomotive power, and for hydraulic propulsion,—but, when established, I trust the remarks I have made in the preceding sheets, on the subject of the comparative power of the two systems, will be sufficient to convey a general, but clear, definite, idea *of the amount of driving power* which either of them can produce, and offer as available; and thus to institute a comparison between them.

I must return, for a moment, to the annual cost of power, on the two systems respectively. I have shown that of Hydraulic propulsion to amount to £450 per mile, *under the most unfavourable circumstances;* and that of steam locomotion to be £1000, *under the most favourable circumstances*; that is, without placing to its debit all it has to account for, nor investigating the amount of this charge on the most expensive lines. I therefore anticipate that in assuming that the annual expense of power in hydraulic propulsion, would be only to one-third of that, which arises on the locomotive system, the public will consider that I have not exceeded the probability, and that the result may be expected to fully justify the proportions here assigned. If, however, it should prove to be the general opinion, that, on this

head, I claim too much for the hydraulic system, I shall be quite willing to alter the figures accordingly. But, proceeding now on the basis, that hydraulic power will cost annually one third of that of locomotive power, the main question, between the two systems, as far as the public in general, and railway proprietors in particular, are concerned, now presents itself and requires notice; it is this: Taking the cost of furnishing locomotive power annually to the whole railway system, as one sum, and comparing it with that, which might be due to hydraulic propulsion, what would be the nature of the whole difference; what would be the nature of the public benefit?

At this moment I cannot lay my hands on a paper, which I thought I was in possession of, stating the whole annual expense of 'maintenance of the way,' for most of the principal railways now in operation. I am extremely sorry that I cannot therefore offer my readers the precise data, on this subject, which I should much wish to lay before them. I have, in a note, a few pages, back, intimated, that I have not a moment to lose, if I am to complete the publication of this pamphlet, before the British Association, now assembled here, in Manchester, close their short annual session. Under these circumstances, I can only offer, in reply to the question which I have imagined as being proposed, the best information, my recollection will afford; and if in its main features, it is materially inaccurate—particularly, if those features are exaggerated — it is open to correction. Speaking, then, from recollection, but with some confidence as to the substantial correctness of my statement, I believe the annual gross receipts of the British railways will be found to be about £3,000,000. per annum.

I also believe the whole "maintenance of the way," in the most extended meaning of the term, will, on those railways, be found to absorb, more than one half of the above gross receipts; but say half; and the annual expense, under this head, will amount to one million and a half. Now out of this sum for maintenance of the ways, I believe that nearly half must be charged to the locomotive department; comprising, as it does, within it, wages of drivers, stokers, and cleaners of the engines; also wages to the great establishments at the locomotion workshops; likewise materials, being principally metal (iron and

brass) therein worked up; as also new engines and tenders annually purchased of engineers; not forgetting the very heavy expense of coke; nor altogether losing sight of the minor charges for tallow and oil, and stationary engine power to water the engines, &c. Still, as it is not prudent or proper to throw oneself open justly to the charge of exaggeration, I will now, in the absence of sufficient data, suppose the annual cost of the locomotive department to comprise one third of the charge, due to the general term, of 'maintenance of the way.' We have, therefore, half a million of money annually to place against the locomotive department of the British railways. Now, extraordinary as it appears, I trust, I have shown there are sound gounds for concluding, that two thirds of this half million of annual expenditure might be saved, and a large proportion of that sum, preserved for the public, if hydraulic propulsion became the general means of transit. Thus, therefore, I reply to the question, as to the nature of the advantage to accrue to the public, from extensively adopting hydraulic propulsion, as the driving power on railways.

I believe it is incumbent upon me in justice to the invention I offer to public notice, to say a word or two, of merely a personal nature. There is in society, a body of individuals, who, if anything of an advantageous nature is proposed to them, immediately turn round upon you with the question; "then why don't you bring it forward?" It is a question which embraces a single idea only, without recollecting there are always collateral considerations. It is easily considered, in the present instance, by my stating that I have not £5,000 or £6,000 to spare; and that such a sum would be required to give the system a fair *practical* trial; and I am fully entitled to add such a sum *only*, when the magnitude of its operations on its success, are borne in mind, being once fully established. As for the paltry little model trials which, are sometimes proposed as the tests of extensive inventions; they are totally useless and absurd. This is the opinion of one of the first railway engineers in the country, whom I consulted on the subject of constructing a small model; and who replied "No engineer will look at such things." The slightest difference in the proportions of a small model in machinery—so slight apparently, as scarcely to be detected by a

party, who does not know where to look for it—will often give, or take away, as the case may be, from 25 to 50 per cent of advantage in model machinery.

I am also strongly impressed with the idea, that when any invention is brought forward, which appears *likely* to become of public benefit, it is hardly correct or proper to throw upon an inventor, the whole herculean task of bringing it into a state of full operation; and if such heavy, interminable, costly work is to be thrown upon the inventors, I believe there are few, who will not at length declare, that in justice to themselves, a period must be fixed for terminating the treble personal expense, of time, purse, and health.

I make no doubt that *some* objections might still be found, for raising a doubt as to the practicability of this invention; just as might be done in the case of every other. But, if this negative ability is to prevail, and every possible obstructive doubt, is to be removed, before anything new is undertaken, what will be undertaken? If this sort of prudence had been the directing influence; these, within our own times, would have been some of its fruits: we should have been saved the "risk," of establishing the whole railway system; we should not have undertaken the "doubtful" measure of crossing the Atlantic by steam; we should have been six months in travelling to India, instead of two; we should never have thought of the penny postage; and should have preserved a heavy tax on the correspondence of friendship, commerce, and labour; and we should totally have discouraged the establishment of Mechanics' Institutions, public gardens, and large scientific associations; nay, I doubt much whether Davy's Lamp would have been safe; for, it does not meet every possible contingency, nor obviate every cause of explosions in mines.

I beg I may not be misunderstood in the preceding remarks; there are objections as respectable as others are futile; in fact, the former is often valuable to an invention; and it is only by the expression of such, that difficulties in the way of success, which may have escaped the notice of an inventor, can become known to him, and that an opportunity can be afforded, of removing them; that is, supposing them to be of a nature to admit of correction. To produce an instance, however, of ill-founded ob-

jections; we will suppose it should be said, hydraulic propulsion could not succeed, for it could give no alarm; it had no whistle! Individuals of a mechanical turn of mind would immediately answer; surely this may be remedied; it cannot comprise any insuperable objection. The fact is, I intended to have explained a little arrangement for giving an alarm, earlier in the pamphlet, but it escaped my recollection, at the time. However it is this. Run a small elastic strap over a pulley on the axle of the hind pair of wheels, and bring it up through an opening in the bottom of the truck, into the driver's compartment; then pass it over a loose pulley, when not required to be in use, and move it on to an adjoining fast one, when its assistance is required. Now let this fast pulley, by the aid of a small crank, work a *small* pair of bellows communicating with three or four little, high-toned, shrill organ-pipes or whistles; to them, attach keys; and the driver or guard will then be enabled to convey as many alarm notes and intimations along the line as could possibly be required. I am rather surprised the guards, seated on the tops of the coaches, on the locomotive system, have not something of this sort to convey their communications, and orders to the drivers on the engines.

I mentioned in an early part of this treatise, that the circumstances of the case, seemed to require that, before concluding this pamphlet, I should bring hydraulic propulsion into a state of fair comparison with the atmospheric railway, as the two systems were, by many individuals supposed to be analogous in character;* and that whatever position one might stand in before the public, would be equally that, due to the other. I will dispose of this subject in a few words: the atmospheric system proposes to work under half an atmosphere; the hydraulic, under six atmospheres; the atmospheric proposes to lay a driving-pipe along the whole section of the line, of, from 15 to 18 inches in diameter; the hydraulic requires a pipe of 12 inches diameter over one-third of the whole line, aided by light additional skeleton and feed-pipes; the first has to incur the heavy expense of boring the pipe; the second has not; the first appears, from the power of the engine, which is to work the Dalky-extension of the Dublin and Kingstown Railways, to require fully four times the steam power of the second; but this should not be insisted upon, as

* I must here again refer to note B.

the second requires propulsion-receivers and air-vessels, which the first does not; and also will take more valves; and the hydraulic system has manifestly power to ascend the steepest inclines, and even to turn them to beneficial account, while the amount of power to meet inclines on the atmospheric system, is, in Sir Frederick Smith, and Professor Barlow's report, considered not so great as had been imagined. The relative expense of the two systems, compared with their power, &c., I have already alluded to. And, after having, in this little work, furnished all the information in my power on the hydraulic system, if my readers should desire to test this any further, by instituting a more extended comparison between the hydraulic and atmospheric railways, and their several characteristic features and forces, under like conditions, I think Sir Frederick Smith and Professor Barton's joint report, above alluded to, will be found to touch upon everything material in the arrangement of the atmospheric system. To that public report, is appended an admirable letter from Mr. Pim; to which, indeed, the report may, I believe, be considered as the observations of the Government Agents in reply. It will remain for my readers to decide whether I am correct, when I state, I imagine that from Mr. Pim's letter, if allowance were made for the comparative state of the forces and peculiar characteristics of my system, several excellent arguments might be adduced in favour of hydraulic propulsion.

In concluding these sheets, I feel I ought to express my regret at their hurried, and, therefore, imperfect state; but, however imperfectly I may have accomplished my undertaking, I hope I have done enough to leave on the minds of a large portion of my readers, the strongest impression, that hydraulic propulsion will prove:

1st.—Of extraordinary power.

2nd.—Economical, as a working railway.

3rd.—Cheap, for the establishment of new railways on its principle.

4th.—Essentially safe; and secure against collisions of trains, running off the line, and *fire*.

5th.—Regular in time of arrival, and in always maintaining a uniform and high speed.

7th.—Highly condusive, as the above particulars imply, to *public and individual* advantage, and to general convenience.

NOTES.

NOTE A, PAGE 13.

The work on hydraulics, to which the inquirer into the principles of that science is generally referred, as being of the highest authority, and as containing the best data and formulæ for the right base and construction of his sentiments and conclusions, is Tredgold's "Tracts on Hydraulics." This work contains three tracts, which are edited by Mr. Tredgold; who has also added some notes. The first tract is Smeaton's, "On the power of Water and Wind to turn Mills, &c.;" the second contains "Venturé's Experiments on the Motion of Fluids;" and the third is "Dr. Young's Summary of Practical Hydraulics, chiefly from the German of Eytelwein."

Smeaton's tract has not reference to the subject of this pamphlet. In his preface, Mr. Tredgold speaks thus of Venturé's :—"In judgment, he seems as much inferior to Smeaton, as he is superior to him in mathematical learning. Hence, it will be found he sometimes builds too much on the data of his experiments." But on the subject of the third tract, the following observations will be found, in the preface to the general work :—

"Of the value of Dr. Young's Summary of Hydraulics, we have already given our opinion in the advertisement which precedes it; and we have only to add, that the motion of waters in rivers, the inclination of their surfaces, and the velocity of water in pipes, are there given in more clear and brief manner than in any other work extant; and may be usefully referred to in questions relative to the right cf water in arbitrations, &c. as well as in calculations for new water works."

Mr. Tredgold's opinion just alluded to, as appearing in his advertisement or introduction to Dr. Young's tract, is as follows :—

"In the practice of a civil engineer, much of his success depends on

a sound knowledge of the principles of the motion of fluids, and of the circumstances attending such motions; at the same time, few have leisure to enter into such inquiries, unless they be brought before them in a condensed form, with clear directions for their immediate application to practice.

"A work of this nature having been published in Germany by Professor Eytelwein, an abstract or summary of its contents was drawn up by Dr. Thomas Young, with such modifications and improvements as he considered would add to its value to an English reader. This summary was first published in the journals of the Royal Institution, in 1802, and the importance of so comprehensive a view of the doctrine of hydraulics, being immediately connected with the preceding experimental papers, was so evident, that we solicited Dr. Young's permission to republish it; and it was granted in the most kind and liberal manner."

There is an important chapter, and one of the longest, in Dr. Young's tract, with a very material extended note on it from Tredgold, from the formulæ in which I take my data, in this pamphlet, for establishing, and proving the beneficial results to accrue from applying hydraulic propulsion as the driving agent on railways. But while the article on "the motion of water in pipes," (chapter 13), is fully sufficient, clear, and satisfactory, for all practical purposes—or if it err at all, it is, as I think I shall be able to show, on the safe side—I cannot but regret that in Dr. Young's work of twenty-four chapters, but one should be devoted to that important subject; comprising, as it does, in it, the leading principle, which governs the supply of all waterworks; and which, very probably, also contains within it, much power available to other important purposes, without considering how far its influence may affect and confirm to the principle of railway hydraulic propulsion. Dr. Young's tract, however, as intimated in the text, is not singular in this respect, particularly when the working out of this principle on a large scale, is in question; indeed, if the work alluded to be singular at all, it is in bestowing more attention to this subject, than is to be met with in some other writings. But I shall have to recur to this; and then I think I shall be able to establish, at least a strong probability, that the formulæ or rule—on which on the present occasion, and in default of better data, I am ready to base the claim of my invention on public notice—will be deficient in amount of result.

Note B, page 20.

On the subject to which this note refers, I now insert below an extract from a letter addressed to me by the editor of a periodical of very extensive circulation. One or two remarks in it might appear to be not in the best taste (for publication) as they allude, rather in unfavourable terms, to another invention for propulsion, now before the public; namely, the atmospheric railway. I have, however, submitted the extract to the consideration of some judicious friends, and they are of opinion, in which I concide with them, that the circumstances of the case will render it imperative upon me, in the course of this work, to separate and distinguish the leading features of my invention, from those, which characterise that of the atmospheric system. This can now be done, subject to a less unfavourabe construction, than might have been the case some months back; as the Dublin and Kingston Railway Company have resolved to extend their line about a mile and three-quarters (to Dalkey) on the atmospheric principle. The ultimate position, therefore, which the atmospheric railway must shortly assume in public estimation, can no longer be affected by the remarks of any writer whatever on its subject, whether favourable or otherwise: its character and capabilities will be determined by the results of the trial, to which its powers are now being practicably submitted by the Dublin and Kingston Railway Company. At the same time, any remarks I may have to offer, in the way of bringing into fair contrast, the principal characteristics of my own, with those of this very ingenious and skilful invention, shall certainly be as brief as the subject will admit of.

Extract.—January, 25th, 1842.—"Whatever plan you adopt, it will be highly advisable, in drawing up your description, to assume that little, if anything, is known of the nature of your patent. It may even be necessary to ensure its being perfectly intelligible—and it is only by making it so that you can expect it to be appreciated as it deserves—to explain any principle of hydrostatics, which is not at once obvious, or at least, very generally known. This is the more necessary, as an opinion has gone forth that the pneumatic railway is a failure; and with those who know nothing more of yours than the name, it is apt to be considered an analogous attempt. I do not say this without reason. I

have again and again heard the assertion made ; and you may depend upon it, that your patent would have had a fairer chance of being speedily adopted, had the pneumatic railway never been proposed."

Note C, page 24.

" Since falling bodies are in this manner accelerated (*i. e.* as the odd numbers) it may seem difficult, perhaps to conceive how a perpendicular pipe fixed at the bottom of a vessel of water, should continue, during the efflux, always full; which, strictly speaking, ought not to be so, on account of this acceleration, which ought to cause the water to run out of the pipe faster than it really could come in: whence it might be apprehended, that in time the pipe might be empty, before the water was all out of the vessel. To which we reply, that though *all bodies are by gravity accelerated in their fall, in the proportion of the odd numbers, already mentioned;* and must allow that if two heavy bodies A and B, be let fall one second after another, the first would get ahead of the other; nor would they keep at an equal distance during their descent. For, if at the end of one second after A is let go, B should be delivered, the first would be proceeding at the rate of 3, while the other is getting on but at the rate of 1. During the third second, A will be urged on with the force of 5, while B can have obtained the celerity but of 3. So that, if at the end of the first second, they were but a rod asunder, at the end of the second, they would be three rods apart, five at the end of the third, seven at the end of the fourth, and so forward, progressively. Yet it ought here to be considered, that the water in our perpendicular pipe, does not run into and out of it successively, and by starts, but evenly and continually. And though by the acceleration of falling bodies, their velocity does increase, on which account the water, in its progress through the pipe, if the resistance of the air, and every other impediment was away, might be allowed to be a small matter rarified; yet as the particles of water contained in the descending pillar set forward one after another in spaces of time infinitely short, and, being tenacious, adhere pretty well together, they appear, as to the sense, to make an even stream, and full in every part. It is, therefore, impossible that, so long as there is water in the vessel for a supply, such pipe should become void of water, nor is the objec-

tion any more than a nicety."—*The Motion of Fluids, by Mr. Clare, A.M. and F.R.S., second edition,* 1737.

The above extract may possibly, to parties who have not attended to hydrostatics, convey several ideas that will be new to them, the importance of which in the science, they will probably, now they are brought before their minds, be able, in some degree, to appreciate. Some of Clare's *reasons,* however, will, on a little reflection, probably appear not so indisputable as his facts.

Note D, page 26.

"The author (Young, on Eytelwein) has attempted to simplify this subject nearly in the same manner as that of the motion of rivers, and apparently with considerable success. He observes, that the head of water may be divided into two parts, one of which is employed in producing velocity, the other in overcoming friction: that the height employed in overcoming the friction must be as the length of the pipe directly, and also directly as the circumference of the section, or as the diameter of the pipe, and inversely as the content of the section, or as the square of the diameter; that is, on the whole inversely as the diameter; this height, too, must vary, like the friction, as the square of the velocity."

(Here follow algebraical formulæ, too long and complicated for any but a professed mathematician to work out, even if he would willingly encounter it practically; but at the foot of the paragraph is a valuable note by Tredgold, from which I extract as follows):—

"From this equation some exceedingly useful practical rules may be derived. In its present shape it only shows the velocity of water flowing through pipes; and is equivalent to the following rule:—

"To determine the velocity of discharge of a pipe, when the height of the water in the reservoir above the point of discharge, and the length and diameter of the pipe are given:

"Rule.—*Multiply* 2,500 *times the diameter of the pipe, in feet, by the height in feet, and divide the product by the length in feet, added to* 50 *times the diameter, then the square root of the quotient will be he velocity of discharge in feet per second.*

"Example.—Let the diameter of the pipe be ·375 feet; the height of the water in the reservoir, above the point of discharge, 51.5; and the length of the pipe 14637 feet. Here

$$\frac{2500 \times \cdot 375 \times 51.5}{14637 + (50 \times 375)} = \frac{48281 \cdot 25}{14655 \cdot 75} = 3 \cdot 3$$

very nearly, and the square root of 3·3 is 1·816; hence the velocity is 1·816 feet per second. These are the measures of one of the Edinburgh water pipes, described in Smeaton's Reports (vol. 3, page 231, first edition), and the actual velocity, it appears, was 1.815 feet per second." —*Tredgold's Tracts on Hydraulics, second edition, page* 205.

This rule will be found to give the initial as well as final velocity; that is, the velocity due to water freely discharging itself at the foot of any length of vertical piping, as well as that due at the further extremity of any extent of horizontal pipe, when such pipe is, at the other end, connected with any pillar of vertical piping. In the latter instance the rule must be accepted exactly in the terms in which it is proposed; while, in the first, that part of the rule which instructs us to "divide the product by the length in feet, added to 50 times the diameter," must be understood as giving "50 times the diameter" as the divisor only, there being in this case no horizontal length.

NOTE E, PAGE 31.

This anticipated reduction in the retardation of water in large pipes, till it approaches the cube inversely, instead of the square, I think may be satisfactorily accounted for. Let the retardation or friction alone, when unaided by any material momentum, be taken to be, as commonly understood, inversely as the square. Then, when the impetus of a powerful momentum comes into full play, it cannot surely, with any regard to accuracy, be left out of the account. Let us assume, in default of sufficient data, that it will possess an influence in proportion to the bulk when multiplied into that velocity, which the rule I have quoted, assumes as being due to a column of water, under any given conditions: then, the advantage gained by the decreasing retardation, due to increased bores, being multiplied into the above required quotient, will most probably furnish a result very near the truth, and in which the square will be rejected, and the cube approximated.

NOTE F, PAGE 81.

Throughout this little work, hydraulic propulsion has been reviewed only in as far as it has reference to the railway system; but it would be very inaccurate to imagine its prospects of usefulness terminate with its application to this great mode of transit. It offers, also, advantages and favourable results in other directions, scarcely less important than those above alluded to. The capability, in hydraulic propulsion, of adapting its power and first cost to the proportion of velocity which there are means to purchase, constitutes one of its greatest merits, when looked at in the widest public light. If it could be established, with equal cheapness for high, as well as slow speeds, it would offer the railway system further ability for putting (as it were) out of the question, all other modes of conveyance, however useful they may be, which do not possess qualifications capable of successful comparison with the distinguishing characteristics of a modern railway. But while it can afford both power and velocity to railways at a proportional expense, it can also offer to colliery tramways, or to stone or iron tramways, to be laid on high roads, or to branch railways, where a moderate speed would be considered sufficient, as well as to canals and rivers, where haulage is employed—very great capabilities of transit, at speeds varying from six to ten or twelve miles an hour; and this, too, at a very moderate first outlay. The agency of air-vessels, propulsion-receivers, propulsion-feed-pipes, &c., is requisite on the railway system, to obtain high speeds without great retardation; but when a great velocity was not required, these media might—with the exception of one propulsion receiver for about every two or three miles, to reverse the action of the propulsive power—be dispensed with, their first cost might be saved, and a fair moderate speed obtained from the hydraulic current being discharged directly upon extensive lengths of driving pipes, and without any intermediate agency whatever. The propulsion-pipe also might be much reduced in diameter where a very great speed or tractive power would never be required; and it will, therefore, be evident, that the amount of first power might equally be lowered. Such things would make a very great alteration in the first cost. Besides, water-power would be more frequently obtained in the hilly districts, through which roads, tramways, canals, and rivers

often wind their course. The valves, also, to work such an adjustment of the system, might be reduced to two or three for every couple of miles. Lastly, the drainage-water—often running to waste—which such a system would gather from the sides of the hills, along with the small and, at present, useless streamlets, which it would unite, might constitute it the means of rendering essential service to agriculture. All such waters, after doing the driving work of the system, ought to be conveyed to reservoirs, fixed in convenient positions, whence the liquid might be distributed, for the purposes of irrigation, to any locality, permitted: thus sometimes becoming, not only greatly beneficial to the farmer, but also a source of profit to the company. As a hauling power along canals, hydraulic propulsion would adapt itself to slow speeds with peculiar effect. Four to six miles an hour, appears sufficient on canals, established for the conveyance of merchandise. This would allow of considerable sections of propulsion-pipe being established, without intermediate agency, on each side of a first power station. The regularity in the operation of the system, would prevent many stoppages and much confusion, and probably allow of a larger traffic being passed along a canal than is practicable on the present system. It would take the boats admirably throngh tunnels ; in which, when there was no towing path, the propulsion-pipe might be tied along the top of the roof or arch, with its continuous cleft along the bottom, instead of the top of the pipe; other parts of its machinery being also reversed, in a manner that will be sufficiently obvious. The vessels would require attaching by a towing line, to the power-connexion plate. The canal would be worked in each direction alternately, like a railway of a single line; and some other minor and simple arrangements, on the score of adaptation, would require attention.

OBSERVATIONS

AND REFERENCES

TO THE

FIGURES IN THE DRAWINGS, &c.

OBSERVATIONS.—Hydraulic propulsion is intended to derive its power from the force of water under considerable pressure, in pipes. It is proposed to apply this pressure upon, or behind, a travelling piston in a pipe, and to carry the power so derived, by a flat iron plate, rising out of the crown of the piston, through a longitudinal continuous cleft in the pipe, and then to apply this power, when thus brought out of the pipe, upon a train upon a railway;—the continuous cleft to be filled up by the peculiar working adjustment of a continuous flexible valve, just as the piston passes; and so as to close and make the pipe water-tight, which is behind it, and filled with water. The hydrostatic force of water in pipes, under adequate pressure, is very great; and were there no retarding influence to its free passage up pipes, its application upon machinery would be remarkably simple. It happens, however, that, at high speeds particularly, the friction or retardation in the water increases, with the length of the pipe, very materially. Hence, it becomes necessary to keep each section of the "propulsion-pipe" of a moderate length, to adopt its final velocity as the driving speed, and to run the trains, by the momentum or impetus, which has been thrown into them, from this source of power in the propulsion-pipe, a certain distance further over a section of "skeleton-pipe," without more power being expended on, or rather being made to follow them uselessly, when they are full of driving force. This arrangement will render it necessary for the water, under pressure, being conveyed *slowly*, during the intervals between the passing of the trains by a small additional pipe, to "propulsion-receivers" (or store-receptacles of hydraulic power), to be placed in positions adjoining the sections of propulsion-pipe (as they will occur at regular intervals along

the line,) from which the water may be again discharged, as the trains go by, into those sections of pipe. Thus, this system of propulsion is founded on those laws of hydrostatics, which give power over a limited extent, at a great velocity, and power over almost any extent, at a proportional slowness of speed: and it is from the mutual co-operation, or rather from the reciprocal action of these two laws, in the manner intimated, that railway hydraulic propulsion is enabled to promise that amount of beneficial result, which, in this pamphlet is claimed for it; the authorities for which, are brought forward, and the necessary calculations given.

FRONTISPIECE.—It has been intimated to me, that, as the drawing shows nothing but the machinery of the system, it may, to some, convey the idea, that hydraulic propulsion appears to be replete with it. I have, therefore, thought it well to exhibit a portion of a railway, ninety-two yards in length, as it would appear to the eye, when a train was passing. This extent of line, I have obtained in the frontispiece, on a scale of ½ an inch to the yard, by showing it in two lengths, one below the other. This enables me to exhibit, first, a small portion of skeleton piping, then a "first power station," acting immediately from the pressure of a vertical column of water, brought down by piping, from high ground contiguous to the railway: after that, this arrangement enables me, at the commencement of a section of propulsion-pipe, to show the first motion of the machinery, or, at least, so much of it as can appear to the eye; the remainder of it, being equally diminutive, if thus brought into juxta-position with all the great objects about it; I can then exhibit a train of carriages, headed by the driving truck; and I am enabled to complete the seventy yards of propulsion piping, by showing, the reversing machinery and air vessel in their proper, relative positions: after which, this railway sketch terminates with a few yards of the next section of skeleton pipe. Now, to assist in conveying, from this little frontispiece, a just idea of the proportions of the system, it is proper to state that, though only one line of rails is here exhibited in working order; yet a large portion of the most important part of the system may be rendered common to both lines of rails, just as well as confining it to one only. Another thing also should never be lost sight of; namely, that the machinery which, in the frontispiece, is shown as working 92 yards of railway, *would be all that would be required for two hundred and twenty yards;* the rest of that distance being skeleton pipe, with no working machinery whatever upon it.

REFERENCES TO FIGURES AND LETTERS, &c.

A A.—Skeleton pipe.

B B B.—Vertical column pipe, with its curves, to fall into propulsion-pipe.

C.—Junction of vertical column, and propnlsion-pipes.

D D D.—Propulsion piping, one inch in thickness.

E.—Water thrown into propulsion-pipe, behind the travelling piston, by the partial lifting of the communication valve.

F.—Communication valve.

G.—Interception valve, closed against its seat, being thrown up by the first rush of propulsion water, through the junction C. It will be held upon its seat till the pressure of the water is cut off.

H.—Air valve (Fig. 2) half-open, and only requisite when *t t* are required to act.

J.—Stop valve to arrest the progress of the water when the piston has passed forward, out of the propulsion-pipe.

K.—Discharge spout, which will frequently require to be placed at the other end of the propulsion-pipe, where it joins the skeleton; *i. e.* when the inclination of the piping is in that direction, and when the water must consequently be drawn off at that end, and close to the vertical column pipe.

L L.—Travelling piston, with its guide-neck before it.

M M M.—Pulley wheels to carry and direct the piston and guide-neck. The first pulley, near the snout of the guide-neck, is fixed vertically (there will be a second wheel on the same axis making a pair; the continuous valve, passing along the space, between this pair.) The second pulley wheel is fixed horizontally, and the third, behind the piston, vertically, thus in every direction guiding it clear of the sides of the pipe.

N.—Axle of the driving truck (Fig. 7.)

O O O.—Continuous flexible valve.

P P.—Wire rope to keep up the connection along skeleton piping, with continuous valve in driving (propulsion) piping.

Q.—Power-connection plate, to carry propulsive force up from travelling piston, and apply it on the driving truck.

R R.—Driving truck, front wheels and springs of back ones (in Fig. 1) being moved to keep the machinery clear to the eye.

S.—Air vessel, 7 feet by 4 feet 9 inches, to receive the propulsion water, neutralize its force and break the shock, which would otherwise occur, as stop-valve J closed.

T.—Propulsion receiver (Fig. 3) kept under the requisite air-pressure. These vessels are for storing "power" at distances of 220 yards, along the line. The propulsive water is conveyed up to them slowly, and comparatively without friction, and discharged from them, as a train comes up to the adjoining section of propulsion-pipe at the requisite high velocity. (Drawn to half scale.)

V V.—Iron girths, rising out of hold-fasts, and occurring every four feet, to brace the pipes.

U U U.—Propulsion receivers feed-pipes.

W W.—Curved branch pipe from vertical column pipe, or first-power station, or propulsion receivers (broken off) to convey propulsion water to driving pipe, belonging to the other line of rails (namely that line not shown.)

X.—Springs of the driving truck, shown in back elevation, (Fig. 7.)

Y.—Brass axle boxes.

Z.—Buffers in front of the truck, the back ones being removed.

Fig. 5.—Transverse section of propulsion-pipe, continuous valve, and guide-neck of piston, showing the iron belt round the guide-neck, which is to connect the arms of the piston valve. This belt is in fact, the piston valve arm divided, in order to carry it round the guide-neck, and then pass it out of the pipe, and for the driver to control it on the truck.

Fig. 6.—Transverse section of continuous flexible valve, guide-neck, and propulsion-pipe, at the girths round the pipe, and hold-fasts; which latter are to fasten down to the blocks or sleepers. (Drawn to a larger scale, as shown.)

Fig. 8.—Sketch (without reference to proportions, for want of space) to bring before the eye, the arrangement of the propulsion, skeleton, and receivers' feed-piping, for working both lines of rails. (See at No. 61, and the following.)

a a.—Communication valve box.

b b.—Ditto ditto rod, and its connecting arm.

1.—Ditto ditto valve lever.

2.—Ditto ditto load arm.

3.—Load to complete the opening of the communication valve.

4.—Lever or arm, to small air cylinder.

c.—Air cylinder, to regulate action of load, 3.

d.—Clack valve of ditto (opening inwards) on one side, and close to the bottom, to allow air to enter freely, as piston rises, when the adjoining leverage is reversed.

e.—Piston of air cylinder, fitting quite loosely, to allow air under it—after it becomes compressed, by the sudden fall of the piston through part of the cylinder, as communication valve first partially opens — to escape gradually rounds its sides, and thus check and regulate the action of the load 3.

5.—Back guide to air piston rod, its front one, not being shown (in section.)

6 6.—First pair of reciprocating levers to convey first move to communication valve from pulley at 12.

7 7.—Rods to above levers, communicating with the second pair at 8.

f f.—Pair of inclined pillars to above leverage, front only being shown at Fig. 1.

8 8.—Second pair of reciprocating levers, the top one of which is shown dotted through at Fig. 1., and shown, looking down upon it from above, at Fig. 4. The bottom lever of this pair is exactly covered by 13, (on which, however, its own number (8) is shown,) opposite to which, it is placed, on the other side of the rails.

9.—Shaft to carry action of reciprocating levers under the rails, from the far to the near side of the line, in order to keep the machinery out of the way of the passengers.

10.—Lever conveying, from its pulley, through shaft 9, &c., first move to communication valve, which it opens about one-third.

11.—Rod to 10.

12.—Pulley to ditto.

g g.—Pillar for above leverage.

13.—Lever to carry motion forward to air valve, H, Fig. 2.

14.—Connecting for above purpose.

15.—Lower arm of bell-crank of air valve, to reciprocate in due relative proportions, for opening and closing action 13.

16.—Upper arm of above bell-crank to communicate closing action through leverage, previously described, to communication valve.

17.—Rod to the above.

18.—Pulley for ditto to act, when the incline on the driving truck lifts it, in passing.

h.—Pillar for above leverage, rod, and pulley.

j j.—Continuous cleft in propulsion-pipe to receive continuous valve as travelling piston passes.

k k.—Iron arch or passage through bottom of power-connection-plate, where it divides to admit continuous valve through (see in transverse section at Fig. 6.)

m m.—Rings of leather or Caoutchouc, nailed down to the piston, on one side of each ring, and forming its gills.

l.—Piston valve, used only to prevent accidents.

19.—Piston valve rod.

20.—Branched part of piston valve rod, to carry it round guide-neck, and so upwards.

21.—Upright rod, being a continuation of 19 and 20.

22.—Head of the above and bar on which it slides.

23.—Connecting rod to the above.

24.—Bell crank to convey action to the above.

25.—Screw with its lever handle, to work the above; that is, through the connecting rods, &c., to open the piston valve, and to close it again.

n n.—Incline or driving truck to throw up pulleys 12 and 18, as the truck passes.

p p p.—Bent, double forked lever, with its long axis, to slot the incline back close to the truck, when the driver wishes to stop the train. This it will cause, by its being thus placed out of reach of the pulley, when the communication valve to throw water into the propulsion-pipe will not be acted upon.

r r.—Rod and handles, to work the above.

s s s s.—Wheels of driving truck.

u u.—Strong springs carrying power connection-plate, and allowing a little play, in case of any unevenness in the rails.

t t.—Two pulleys or friction wheels to put continuous valve down, in case it ever sticks in continuous cleft, so as to enable it to enter *k* freely.

w w.—Supports from driving truck for above pulleys.

26.—Traddle to close stop-valve, acted upon by front pair of pulley wheels M of travelling piston L.

27.—Bell crank, carrying the action of the traddle forward, by the aid of the small connecting rod between them.

28.—Longer connecting rod between the two bell-cranks.

29.—Second bell-crank to apply action of traddle upon stop valve.

30.—Supports from the skeleton pipe, to the two bell-cranks.

31.—Stop valve rod.

32.—Stuffing box.

33.—Stop valve box.

34.—Additional lever to ensure the due opening of the stop valve, if it should even not fall by its own gravity, as soon as water, which holds it, by strong side pressure, upon its seat, is withdrawn.

35.—A support to the above from the propulsion-pipe.

36.—Two prongs to end of lever, which, when not to act, play freely between 31, but in case stop valve ever sticks, press upon boss at 37, and throw it down.

37.—Above-named boss.

38.—Stirrup to 34 playing loosely on boss at the end of 16, except when an obstruction at the other end of the lever (i. e. the sticking of the stop-valve) causes boss to press firmly upon the upper end of this stirrup, and so produce action on stop valve.

x x.—Air-valve box.

y.—Lever with load to assist the leverage to the communication valve in reversing action. It also retains the communication rod at a proper tension.

z.—The above load.

39.—Orifice from propulsion-pipe into connecting pipe, to air vessel.

40.—Above connecting pipe.

41.—Clack valve, opening inwards, in the air vessel, to prevent the recoil of the water into propulsion-pipes.

42.—Air globe (self-acting) to lift small discharge valve, 43, when sufficient water has passed into the air vessel to float the globe. The water, so discharged, is to be carried off in a proper drain, for use again, or to run to waste, as occasion may dictate.

43.—Discharge valve above mentioned.

44.—Manhole. This number also refers to the manhole in the propulsion receiver.

45.—Junction of receivers feed-pipe U, and of curved branch W, with vertical column pipe.

46.—Chairs.

47.—One line of rails.

48.—Sleepers.

49.—Blocks.

50.—Holdfasts to bolt down to blocks or chairs.

Fig. 3.—(Drawn to half scale.)

51.—Connecting pipe to propulsion-pipes, of the same character as the curve at B. The other piping in this figure is explained by the the letters on it (being the same as on the other figures), and is shown without valves, &c., which leaves the propulsion-pipe, and its arrangement, open to view.

52.—Air globe on its lever or guide-arm; to be of **sufficient load to** throw open valve 55, against a preponderating pressure.

53.—Upright rod, down to valve at 55.

54.—Stirrup, through which guide-arm of 52 moves, so as to establish action of valve only just before the full charge of propulsion water is thrown from the receiver into the driving pipes, and so as to close the valve again quickly, just as the receiver is replenished with another charge.

55,—Feed valve between receiver and its feed-pipe U, opening downwards.

56.—Connecting rod from 55 to 57.

57.—Small interception valve and box, to close when 55 is open, and to open when it is closed; thus turning the water into this receiver or allowing it to pass on to the next, as required.

58.—(Figs. 1 & 7.) Partitions in driving truck, inside, to box off so much of the wheels as would be otherwise there exposed.

59.—Guard's box, in that division of the truck which is divided off for him and the driver.

60.—Seats for the guard and driver.

Fig. 8.—*(Drawn without any proportions,* as already explained.)

61.—Vertical column pipe.

62.—Propulsion receivers.

63.—Ditto piping, on one line of rails, to represent 70 yards on each curved line.

64.—Skeleton piping, to represent 150 yards in each small dotted section shown of it.

65.—Propulsion piping, representing (as at 63,) a section of 70 yards, in each branch, to reverse direction of driving power (as indicated at W in preceding figures) for the other line of rails; say, for that, not exhibited in this drawing.

66.—The two lines of rails.

67.—Propulsion receiver's feed pipe.

Manchester: Printed at Simpson and Gillett's Steam Press.